Iron and Steel ENGINEER

NGINEERING SERVICE
) THE IRON AND STEEL
IDUSTRY SINCE 1907

)10 EMPIRE BUILDING APRIL, 1946 PITTSBURGH, PA.
CHNOLOGY DEPT:

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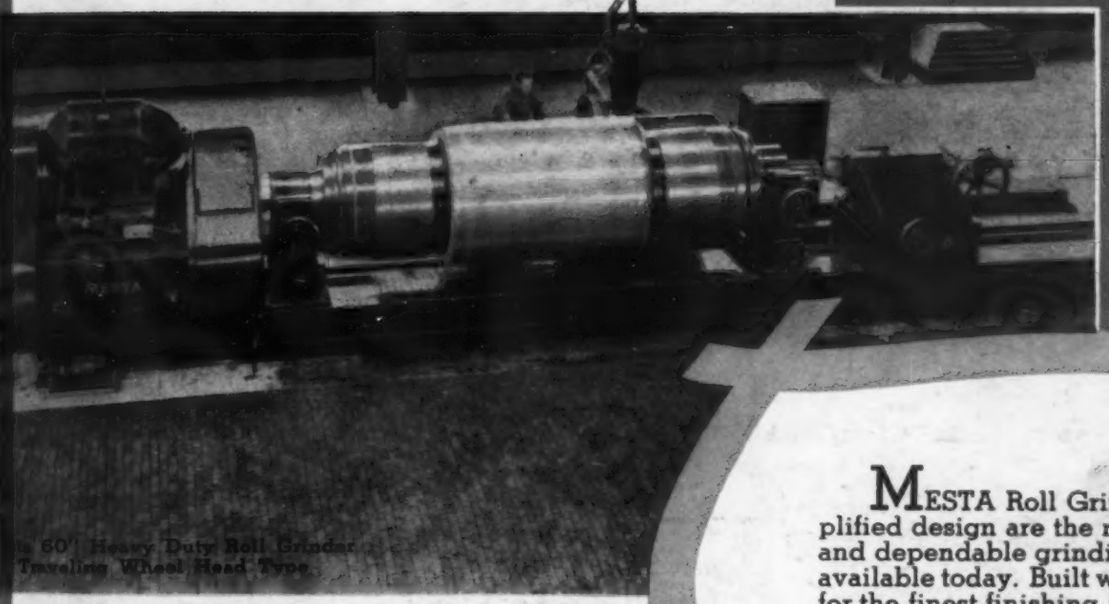
MESTA *Roll Grinders*



60" Heavy Duty Roll Grinder
Traveling Wheel Head Type

MESTA Roll Grinders of simplified design are the most accurate and dependable grinding machines available today. Built with precision for the finest finishing and with ruggedness for the heaviest roughing.

28" Heavy Duty Roll Grinder
Traveling Table Type

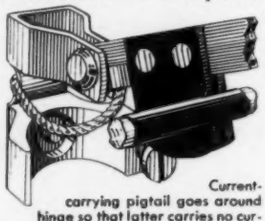
The Army-Navy "E" Flag with five stars flies over the Mesta Plant

MESTA MACHINE CO., PITTSBURGH, PA.

A *New* AND *Better* SAFETY SWITCH

Features of the new and better C-H Safety Switch

Reinforced stationary contact jaws have heavy non-ferrous clips for permanent contact pressure. Withstand 500° F operating temperatures.



Current-carrying pigtail goes around hinge so that latter carries no current. A feature promoting better operation and longer life in Type A switches.

Switch heating reduced by cutting number of current carrying screw joints to only 3 in type A switches—to only 4 in type C.

Perfected arc snuffer confines arc to restricted space and wipes remaining arc from blade as switch is opened. Snuffer readily removed to inspect jaw contact.

And in Addition . . .

1. New modern case design that matches Cutler-Hammer motor control styling.
2. Knockouts that really knock out.
3. Front operation for close ganging.
4. Plenty of room and easy access to shape up wires inside. Easy installation.
5. Knife type blades, solderless lugs, screw type fuse clamps (Type A), strong clips.
6. All parts cadmium plated against corrosion.
7. Assured positive and firm contact even after long use.
8. Contacts on Type A switches are silver plated.

To beat the heat that *all* safety switches generate while they are "on" . . . Cutler-Hammer Engineers designed a NEW Safety Switch. Their first step was to plan a switch mechanism that would carry its load with a new low minimum of heating. Their second step was to build the mechanism so that it would far better withstand the heat produced by the fuses in normal operation. Finally they added plus features which a thorough investigation over a long period of time showed that contractors, electricians and service men want.

The result is an outstanding switch that offers better performance, longer life, easier installation, better appearance, a new measure of safety . . . a switch such as you have never encountered before. Why don't you take the measure of its quality in your very next installation? At Cutler-Hammer wholesalers everywhere. CUTLER-HAMMER, Inc. 1269 St. Paul Ave., Milwaukee 1, Wisconsin.

CUTLER-HAMMER
SAFETY SWITCHES
C-H

Aetna-Standard

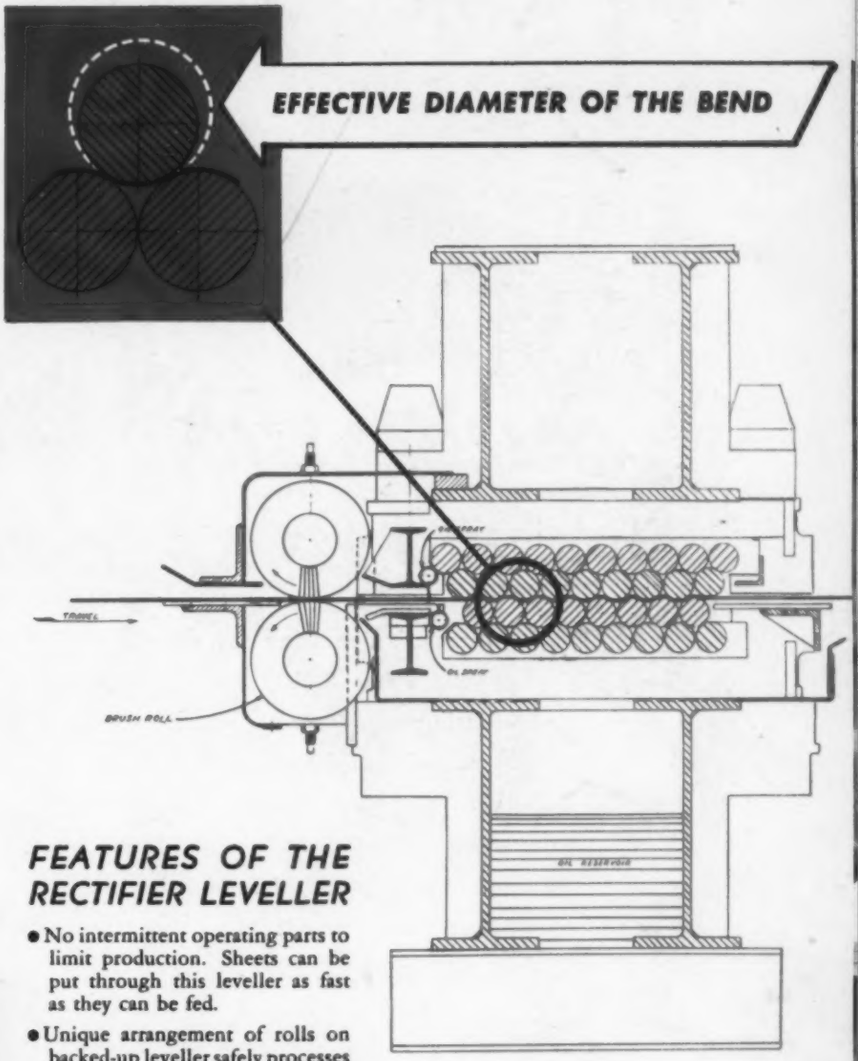
RECTIFIER LEVELLER puts new life into steel for deep drawing

The rectifier leveller has become an important mechanical aid in deep drawing.

Fifteen individual flexing operations, each equivalent to bending around an individual roll of slightly larger diameter, restore much of the original plasticity to steel sheets, strip and blanks.

Material, properly rectified, eliminates most drawing headaches. It takes a deep draw easily and makes possible continuous production with few rejects. Production is accelerated, too, by the replacement of most of the hand finishing. A brush roll and automatic spray cleans and oil-coats the material as it moves through the leveller.

The rectifier leveller is an exclusive design of Aetna-Standard, largest manufacturers of levellers. Several improvements have been made in the original design since the first machine was developed for the automobile industry 13 years ago.



Two sizes... 1¾" dia. up to 72" wide... capable of rectifying material up to 18 gauge... any length, short, medium, or long.
2½" up to 112" wide... capable of rectifying material up to 12 gauge... no limit on length.

FEATURES OF THE RECTIFIER LEVELLER

- No intermittent operating parts to limit production. Sheets can be put through this leveller as fast as they can be fed.
- Unique arrangement of rolls on backed-up leveller safely processes and rectifies sheets, strip or blanks for proper conditioning before stamping or deep drawing.
- No single roll does all the work ... 15 individual flexing operations, each equivalent to bending around an individual roll of slightly larger diameter.
- Brush roll cleans sheet before entering dies. Oil spray coats sheet with oil as an aid in lubricating dies.
- Equipped with recirculating oil system and oil filter which can be cleaned while in operation.

THE AETNA-STANDARD
ENGINEERING COMPANY • YOUNGSTOWN, OHIO

DESIGNERS AND BUILDERS to the Steel, Non-Ferrous and Chemical Industries

ASSOCIATED COMPANIES:
HEAD, WRIGHTSON & COMPANY, LTD., THORNABY-ON-TEES, ENGLAND

CALL IN THE FLUOR 'SPECIALIST' NOW!

Last summer's operating records show what your water cooling requirements were during warm weather peaks. To be sure you maintain the efficiency of your Cooling Towers to meet this summer's demands, let Fluor make this vital Maintenance Check-Up *now* while demands on your towers are lessened:

1. Inspect decks and filling for sagging, accumulation of foreign matter, loss of parts, etc.
2. Inspect distributing system for scale, rust, clogging, leaks, loss of pressure, etc.
3. Determine quality and quantity of water flow. Look for rapid corrosion of metal parts and delignification in the wood.
4. Check flow of effluent air for recycling troubles in mechanical draft towers.
5. Inspect ladders, handrails, stairs and walkways for signs of weakening.
6. Inspect structural members including bolts and castings for cracks, breaks and other causes of failure.
7. Check motors, pumps, gears, fans, couplings and other mechanical equipment.

FLUOR Maintenance and Repair Service covers ALL MAKES and TYPES of Cooling Towers. As manufacturers of Fluor Aerator and Fluor *Counterflow* Cooling Towers, Fluor M & R Service is complete and economical.

SINCE 1890

FLUOR

ENGINEERS • MANUFACTURERS • CONSTRUCTORS

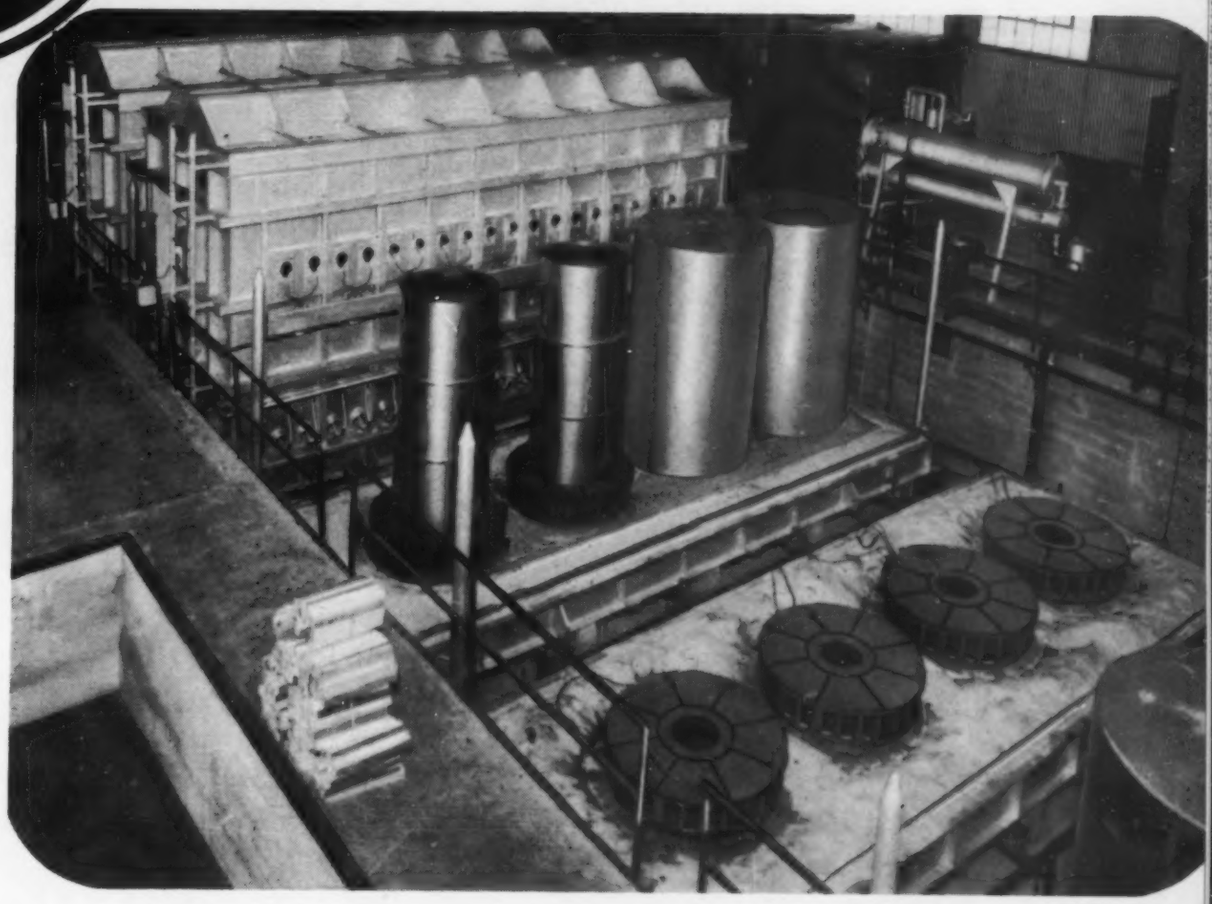
PROCESS PLANTS AND EQUIPMENT FOR THE OIL, GAS AND ALLIED INDUSTRIES

THE FLUOR CORPORATION, LTD., 2500 So. Atlantic Blvd., Los Angeles 22 • New York, Pittsburgh, Kansas City, Houston, Tulsa, Boston

WILSON

Rectangular and Cylindrical Bell Type Furnaces for Steel Coil Annealing

The Wilson Annealing Unit is covered by Patents Nos. 1,952,402, 2,068,477, 2,078,356, 2,081,612, 2,089,843, and other patents pending.



THE Lee Wilson Engineering Company is ready for the new expansion in the strip sheet and tin plate industry.

New developments in the use of radiant tube and convection heating will increase the tons per hour yield in annealing furnaces designed for larger coil diameters and increased piling heights.

ENGINEERED AND CONSTRUCTED BY THE

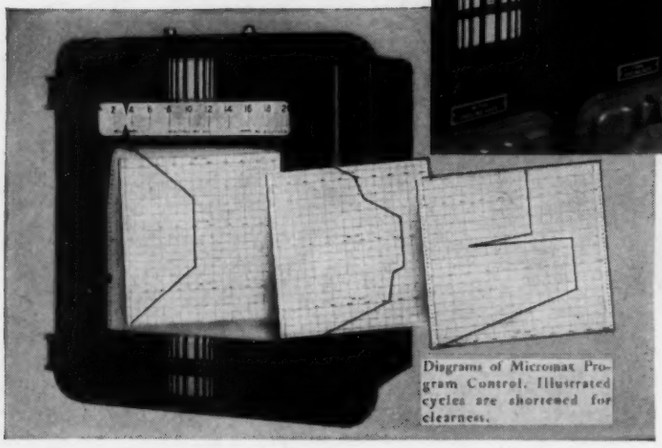
Lee Wilson ENGINEERING Co., Inc.

20005 West Lake Road CLEVELAND, OHIO

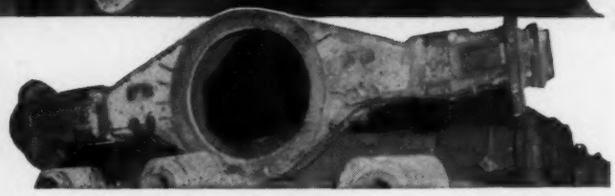
Telephone ACademy 4670

Sold by The WEAN ENGINEERING CO., Inc., Warren, Ohio

INDUSTRIAL FURNACES ★ RADIANT TUBE HEATING ★ HEAT TREATING PROCESSES



Diagrams of Micromax Program Control. Illustrated cycles are shortened for clearness.



Above, Panel of Micromax Program Controllers for Lee Wilson rectangular bell-type Malleableizing Furnaces at plant of Eastern Malleable Iron Co., Wilmington, Del. Above are truck-axle housings, a product of the annealing process.

PROGRAM CONTROL

Increases the Efficiency of Malleableizing Operations

Automatic control of heating, soaking and cooling rates is making an outstanding contribution to the smooth, economical operation of malleableizing furnaces in the plant of Eastern Malleable Iron Co. Furnaces are Lee Wilson bell-type units, fired with producer gas and equipped with automatic temperature control by means of Micromax Program Control Pyrometers.

The Micromax Electric Control system is used, in which the instruments throttle fuel by means of heavy-duty, electrically-powered valve-drives mounted on the covers. The cable switchboard system at the Control Panel permits any Controller to be used with any valve-drive; an arrangement which gives great flexibility of operation. Heating, soaking and cooling cycles, after being manually pre-set, are automatically maintained with fidelity, to preserve the quality standards needed in good malleableizing.

There is a type of Micromax Program Control to meet the needs of practically any long-cycle heating operation, and an L&N engineer will be glad to help select the one you need, or will send a Catalog, as you prefer.

LEEDS & NORTHRUP COMPANY, 4942 STENTON AVE., PHILA. 44, PA.

LEEDS & NORTHRUP

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

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RNACES

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MILL GUIDES

TRANTINYL

QUALITY DISTINCTION

Symbolic of the Ultimate in guide performance

YOUNGSTOWN ALLOY CASTING CORPORATION

Youngstown, Ohio

Arc Furnace Troubles?—

FAULTY ELECTRODE ACTION HANDICAPS FURNACES—PREVENTS EFFICIENT OPERATION. THE REMEDY IS FAST-ACTING "REGULEX" CONTROL:

☛ "Regulex" rotating control accurately controls electrode position during all the changing conditions of the furnace charge, resulting in greater furnace output per kwh input.

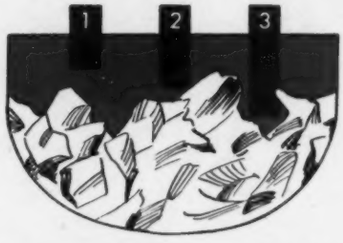
☛ The "Regulex" control system is able to adjust itself instantly to any demand, no matter how small or how large—through sensitive variable-voltage control.

☛ The "Regulex" generator is a sturdy, standard commutator machine, which requires no tricky brush adjustments. Since no springs, levers or contactors are used in the control scheme, maintenance is slashed!

☛ As a unique A-C feature, "Regulex" control can be equipped with flywheels, which automatically raise the electrodes when a-c power fails. The auxiliary generator can make the entire control independent of a d-c shop source when desired.

☛ Your arc furnace manufacturer will be glad to tell you about "Regulex" control for new or existing furnaces. Or write directly to ALLIS-CHALMERS, MILWAUKEE 1, WIS.

Six Conditions "Regulex" Corrects by Fast Action

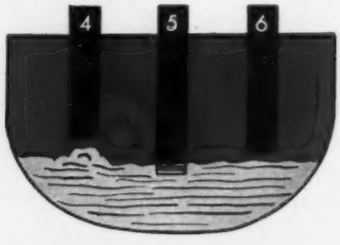


MELTDOWN PERIOD

1. **REPEATED ARC INTERRUPTIONS,** due to sudden "settling" of metal. Sensitive "Regulex" generators reduce arc restrikes—thus meltdown time—by continuous, accurate adjustments.

2. **INSTABILITY OF ARC,** due to inaccuracy of control for raising electrode when short circuit occurs. "Regulex" variable voltage control raises electrodes *just the right amount*—keeps arc values constant.

3. **BREAKAGE OF ELECTRODES,** caused by caving in of metal charge against electrodes. Fast-acting "Regulex" control pulls electrodes safely out of a cave-in. "Regulex" generators also conserve electrodes by reducing number of arc restrikes—thus limiting mechanical shock to electrodes.



REFINING PERIOD

4. **WASTE OF POWER,** as a result of current surges when metal boils up against electrodes. "Regulex" variable voltage control raises electrodes with acceleration directly proportional to amount that arc current and voltage deviate from normal values . . . lower power input results.

5. **FREEZING OF ELECTRODES** in molten bath, due to electrode "drift" when a-c power fails. Only the "Regulex" generator set is provided with a flywheel for automatically raising electrodes upon a power failure . . . preventing electrode breakage, and carbon contamination of the molten metal charge.

6. **BURNING OF ELECTRODES** during refining period, because of using too short an arc. Accurate "Regulex" control permits use of longer arc—conserves your arc furnace electrodes.

Allis-Chalmers

"REGULEX"

Arc Furnace Control

A 1939

HEAR THE BOSTON SYMPHONY: *Every Saturday Evening, American Broadcasting Co.*

18" and 49" x 48" 5-Stand Tandem—4-High Cold Strip Mill

United...

High-Speed 5-stand tandem cold mills

UNITED ENGINEERING AND FOUNDRY COMPANY

PITTSBURGH, PENNSYLVANIA

Plants at PITTSBURGH · VANDERGRIFT · NEW CASTLE · YOUNGSTOWN · CANTON

Subsidiary: Adamson United Company, Akron, Ohio

Affiliates: Davy and United Engineering Company, Ltd., Sheffield, England

Dominion Engineering Works, Ltd., Montreal, P. Q. Canada

The World's Largest Designers and Makers of Rolls and Rolling Mill Equipment

FOR PRODUCTION OF SHEET AND TINPLATE STOCK

UNITED ENGINEERING and FOUNDRY COMPANY, for 40 years leader in the development of cold reduction processes, offers immediately available designs for high speed, high production, 5-stand tandem tinplate mills with finishing speeds up to 5000 F.P.M. Also available are designs for modern 4-stand and 3-stand units.

These mills embody all the latest features in auxiliary equipment including uncoilers, guides, coolant systems, tension rolls, coilers, etc.

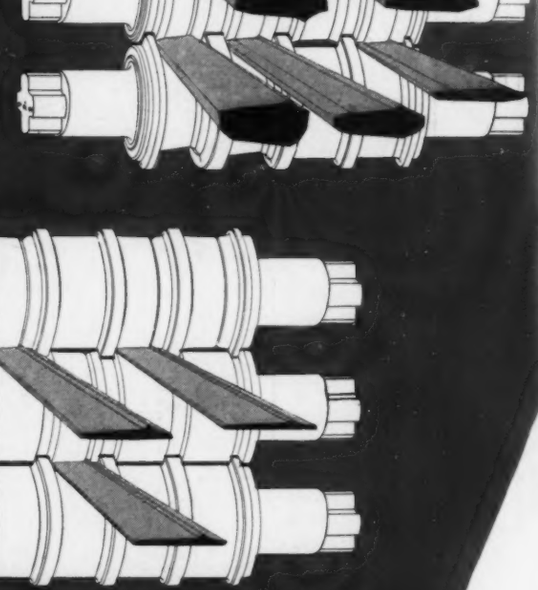
Consult UNITED'S engineers when making plans for reconversion and expansion.

P.R.W

ROLLING TECHNIQUE . . .

P.R.W

Tie Plate



A small piece of steel between the railroad rail and each cross tie might seem unimportant to the average person, but without it heavy or high speed trains could not operate. Cost of track maintenance without these tie plates would be prohibitive. Proper rolls play a large part in producing high tonnage of quality bar to meet present day rigid specifications.

Pittsburgh Rolls, with over three-quarters of a century of roll-making experience and satisfactory performance behind them, can be relied upon to deliver the production of highest quality for which high speed modern mills are designed, at *less cost cost per ton of steel rolled.*

PITTSBURGH ROLLS
Division of Blaw-Knox Company
PITTSBURGH, PA.

PITTSBURGH ROLLS

These New Heavy-Duty INDUSTRIAL EXHAUSTERS *can* SAVE MONEY FOR YOU

Write for Bulletin 3576 which gives complete details including data on use for hot gas application.

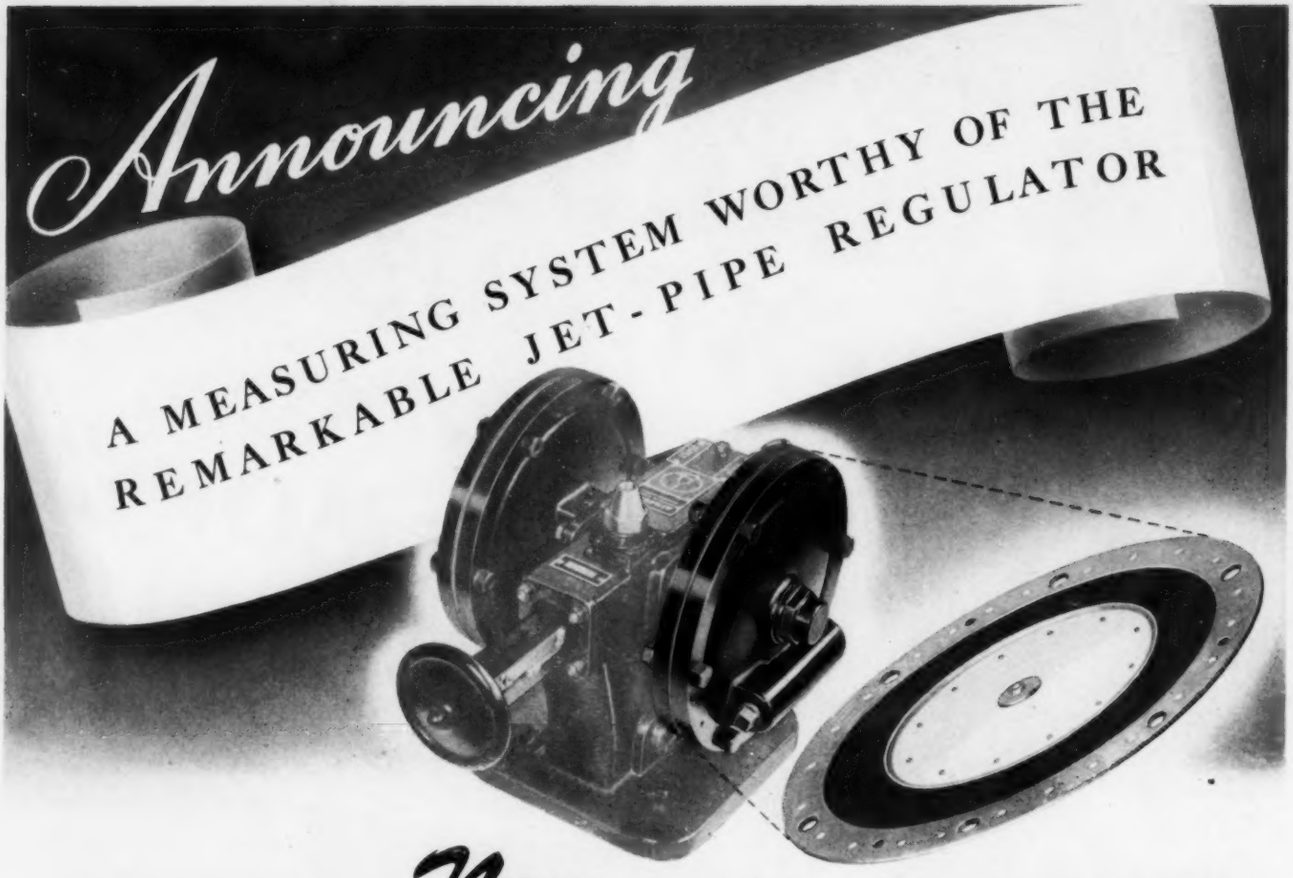
Industrial exhauster service is the most exacting on which fans are used. Generally employed on continuous-service jobs, they are also subjected to fume conditions or material handling, either of which is hard on fans.

The new Buffalo Industrial Exhauster was designed from the accumulated experience of sixty-eight years of fan-building. Sturdy, efficient and practical in design, it is also flexible in application. Reversible as to hand and discharge, it can be furnished with air or material wheel, in a wide range of capacities, belted or direct-connected; rubber-lined if necessary.

All welded construction of housing, rotor and bearing stand provides a relatively light very strong assembly, with improved performance due to absence of bolt or rivet heads inside the housing.

Buffalo Forge Company
173 Mortimer Street **Buffalo, N. Y.**
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

"Buffalo" **INDUSTRIAL EXHAUSTERS**



ASKANIA'S *New* GLASS* DIAPHRAGM

The measuring system of a low pressure regulator is the diaphragm . . . and now . . . for the first time . . . Askania offers low pressure regulators with diaphragms of glass*

With glass* the sensitivity for which all Askania Regulators are noted is retained . . . yet service life of the diaphragm is lengthened many years.

AGAIN IT'S "SET IT AND FORGET IT" WITH AN ASKANIA

For any problem of automatic pressure, flow or proportioning problem or for a sample of the new Askania Diaphragm Glass Cloth* . . . Write Askania Regulator Company, 1601 South Michigan Ave., Chicago 16, Illinois

*Fiberglas Cloth

MEASURING SYSTEMS OF GLASS* GIVE:

Permanent calibration
Long efficient life
Sustained sensitivity
Protection from overload

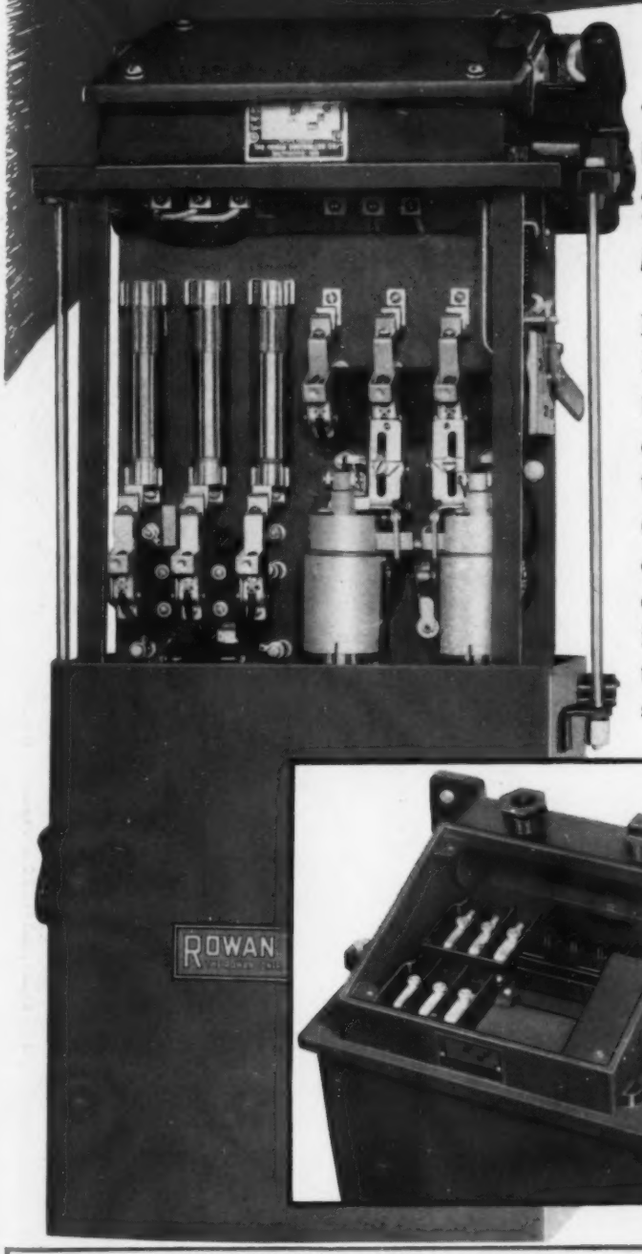
BECAUSE OF

High heat resistance
Non sag or stretch
Constant pliability
Greater strength
Resistance to alkalis, acids and corrosive vapors

ASKANIA
REGULATOR CO. CHICAGO
AUTOMATIC CONTROL

Abreast of the Times!

Reduce Installation Costs And Space Requirements for



. . . Across-the-Line Motor Starting Equipment by using the ROWAN Type 780-KBF Oil Immersed Combination Motor Starter

No special care is required for motor and control leads during installation.

Unit consists of sealed-off terminal compartment, disconnect switch, Rowan Air Seal Fuses, magnetic contactor and magnetic overload relays.

Overload relays are combination of inverse time element and instantaneous operation. Individually calibrated for 110% to 175% operation. Enclosure is mechanically interlocked to prevent lowering of tank when switch is in "ON" position or closing of switch when tank is lowered.

Rowan Air Seal Fuses . . . a proven short circuit protection . . . is a standard feature. Wherever atmosphere is contaminated with corrosive elements, semi-hazardous and hazardous vapors and dust . . . Rowan Oil Immersed Control has proved its dependability and complete safety. Users all over the country testify to its outstanding performance.

Write for complete information on the Rowan 780-KBF and other Rowan Oil Immersed Control Equipment.

MAX. HP AND FUSE RATING FOR 2 OR 3 PHASE, 3 POLE ONLY

FRAME	MAX. HORSEPOWER 25 OR 60 CYCLES		MAX. AMP. FUSE
	220 V.	440-550 V.	
50	5	7½	30
100-B	10	15	60
100-C	15	25	100
150-B		50	100
150-C	25	50	200
300-B	50	100	200
300-C	75	100	400

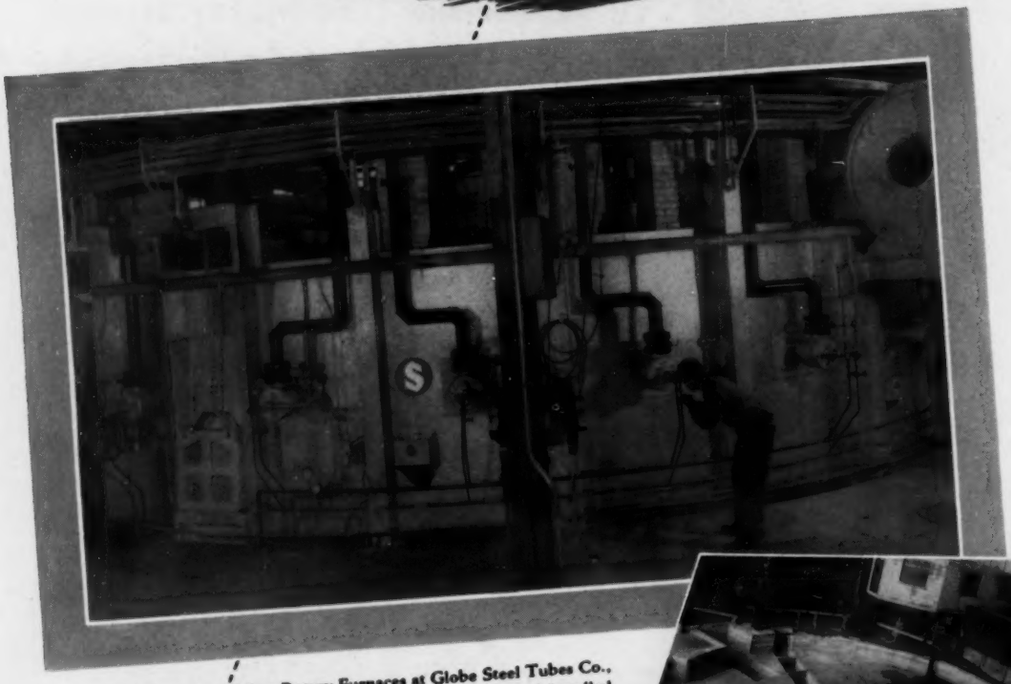
ROWAN CONTROL

THE ROWAN CONTROLLER CO., BALTIMORE MD.

The Rowan Controller Company has specialized in Oil Immersed Controls for nearly half a century.

MODERNIZE

YOUR PRODUCTION WITH *Salem* FURNACES



One of two giant Salem Rotary Furnaces at Globe Steel Tubes Co., Milwaukee, Wisconsin. Designed, engineered, built, and installed by Salem Engineering Company, builders of all sizes and types of heating furnaces and allied equipment.

NEW *SALEM* HEATING INNOVATIONS WILL HELP CUT YOUR COSTS

Here are two examples of how modernized heating can improve production costs.

Salem can tie in all of your heating operations with other production sequences . . . Result—*savings in handling costs alone* will amortize the original cost.

Complete mechanization of heat treating plus elimination of messy operations up production and improves your product quality. . . . These are two of the many ways Salem Engineering Company helps pare costs by modernizing heating furnaces and equipment. Let Salem's engineers apply their peace and wartime experience to your operations.

CALL SALEM . . . originators of Engineered Heat and Builders of the World's Largest Rotary Hearth Forge Furnace.

"Engineered Heat"

SALEM FURNACES

S A L E M

Wherever hot gases need control . . .

Whether it's glass tank, boiler or furnace, superheated gases are quickly and surely put in their proper places by the Morgan Air Ejector. The powerful, continuous stream of cool air directed UPWARD through the venturi throat of the *short stack* draws the exhaust gases out of the furnace . . . causes them to mix with the cooler air within the short stack . . . rapidly discharges them into atmosphere!

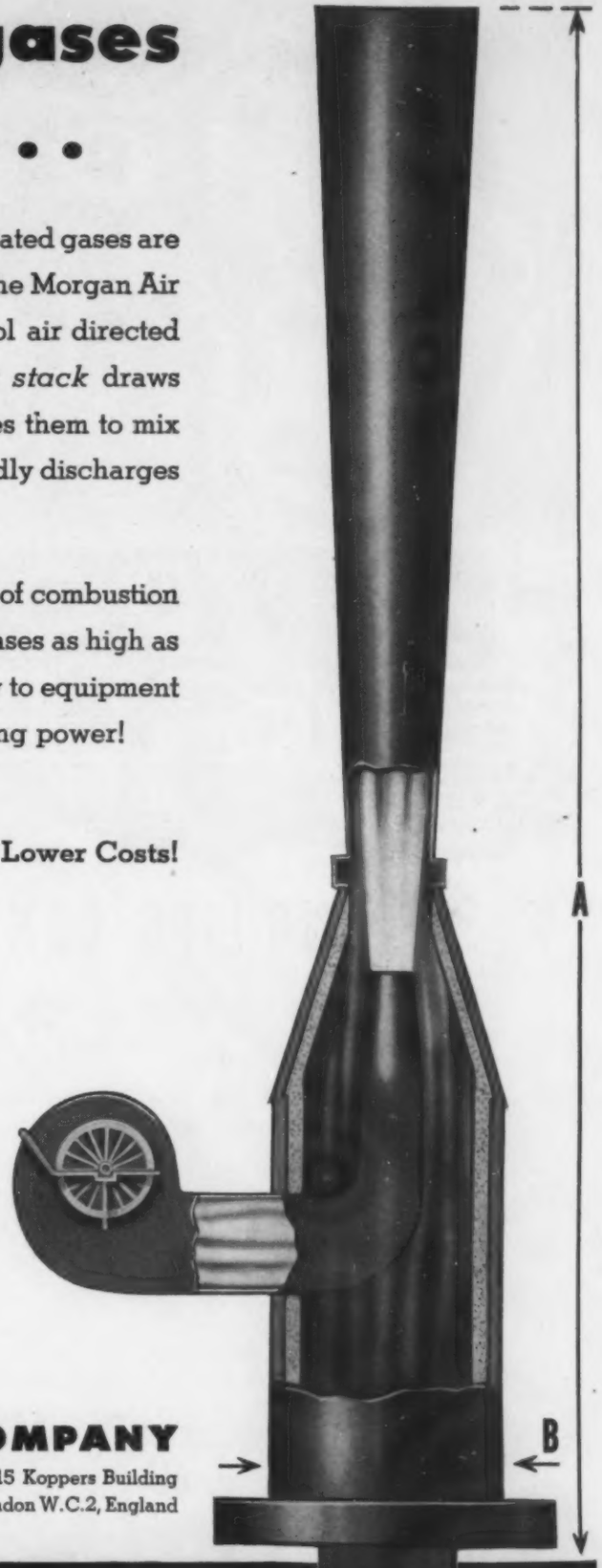
When you use a Morgan Air Ejector the products of combustion *do not pass through the fan* . . . that means gases as high as 3000° Fahrenheit can be handled without injury to equipment . . . without change in the even flow of exhausting power!

It all adds up to . . .
Increased Production, Better Production and Lower Costs!

MORGAN AIR EJECTOR SIZES
(Draft at Base One Inch of Water)

Size	Gallons Oil per hr.	Temp. of Exhaust Gas	Fan Motor H.P.	Dimensions A	Dimensions B
No. 1	50	1000°F	7½	20'–6"	3'–8"
No. 2	75	1000°F	10	23'–8"	4'–2"
No. 3	100	1000°F	15	27'–9"	4'–9"
No. 4	130	1000°F	20	31'–6"	5'–3"
No. 5	175	1000°F	20	34'–11"	5'–8"
No. 6	225*	1000°F	25	38'–6"	6'–2"

*Capacities available, up to 1000 gals. per hr.



MORGAN CONSTRUCTION COMPANY
WORCESTER, MASS. PITTSBURGH, PA., 2815 Koppers Building
English Representative, International Construction Co., 56 Kingsway, London W.C.2, England
CCC-3

Use the MORGAN WORCESTER **Air Ejector**

A LONG-LIFE CONVECTION BASE DESIGNED FOR *Heavy Coil Loads*—

This new patented Base was designed especially for standing up under the heaviest coil loads in Cover Annealing furnaces. It maintains its original true alignment, without sagging, for a long time, therefore permits maximum safe piling height. It also affords more uniform heating and improved distribution of prepared atmosphere.

The first Seven of these Bases, installed in a large Eastern steel mill, showed this remarkable record: *In 5½ years, an average of 412 annealing heats, on heavy coil loads, without rebuilding . . . many times better than any previous record in the same mill.*

FOR ANY COVER FURNACE

These bases may be designed for use with any Cover Furnace—including, of course the F.E.I., the latest and most outstanding development in the production heat treating of coiled strip, wire, rods, flat sheets and tin plate . . . furnaces which every day are winning new laurels in the fast production race, by stepping up output as much as 60%, (even on old furnaces converted to the F.E.I. system), while improving quality and reducing unit costs by a large margin over best previous records.

Ask for further details about these two new developments, including Performance Records.

FURNACE ENGINEERS, *Inc.*

Specializing in the design, manufacture and installation of furnaces for the metal working industries

1551 WEST LIBERTY AVENUE ★ PITTSBURGH, PA.

FACTS YOU SHOULD KNOW ABOUT ELECTRODES

Are you familiar with the mechanical properties of electrodes? . . . Do you know the different types of electrodes for welding cast iron — mild steel—high tensile, low alloy steels . . . which electrode will do the job better, faster — at less cost?

This, and other vital information is all contained in Airco Catalog No. 120. Compiled by leading technicians in the field, this definitive work gives authentic, understandable information on electrodes . . . application, welding procedure, mechanical properties and specifications are thoroughly covered.

Every metal man will find almost daily use for this big, helpful manual. It will save him time, effort and needless worry. It will answer almost any question regarding the proper electrode for welding any particular base metal — for any given type of work.

Send for this valuable, informative guide today! Just fill in the coupon, and mail it to: Air Reduction, General Offices, 60 East 42nd Street, New York 17, N. Y. In Texas: Magnolia Airco Gas Products Company, General Offices, Houston 1, Texas. Represented Internationally by Airco Export Corporation.

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60 E. 42nd Street
New York 17, N. Y.

Please send me a copy of Catalog 120.

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AIRCO AIR REDUCTION

Offices in All Principal Cities

HEADQUARTERS FOR OXYGEN, ACETYLENE, AND OTHER GASES...CARBIDE...GAS WELDING AND CUTTING APPARATUS AND SUPPLIES . . . ARC WELDERS, ELECTRODES AND ACCESSORIES

8 IMPORTANT REASONS—

Why It Will Pay You to Specify

RELIANCE Series "C" MOTORS

1. **Protecting enclosures** keep out dirt, chips, oil, excess moisture.
2. **Steel stators for strength.**
3. **Thirteen-step winding treatment,** for maximum stator protection.
4. **Pressure cast aluminum rotors** provide trouble-free windings.
5. **Heavy shafts,** liberally designed for added strength.
6. **Precision bearing mount** affords *real* protection to bearings and windings.
7. **Optional lead outlet arrangement** permits machine mounting with elimination of conduit box.
8. **Flange and face type brackets** offer alternative methods of machine application.

Write today for Bulletin C-118 which gives more complete details on these 8 advantages and offers many additional reasons why it will **pay you** *to specify Reliance Series C Motors.*

RELIANCE ELECTRIC & ENGINEERING CO.

1084 Ivanhoe Road **Cleveland 10, Ohio**

Birmingham • Boston • Buffalo • Chicago • Cincinnati • Denver • Detroit
Gary • Greenville • Houston • Kalamazoo • Kansas City • Knoxville
Los Angeles • Milwaukee • Minneapolis • New Orleans • New York
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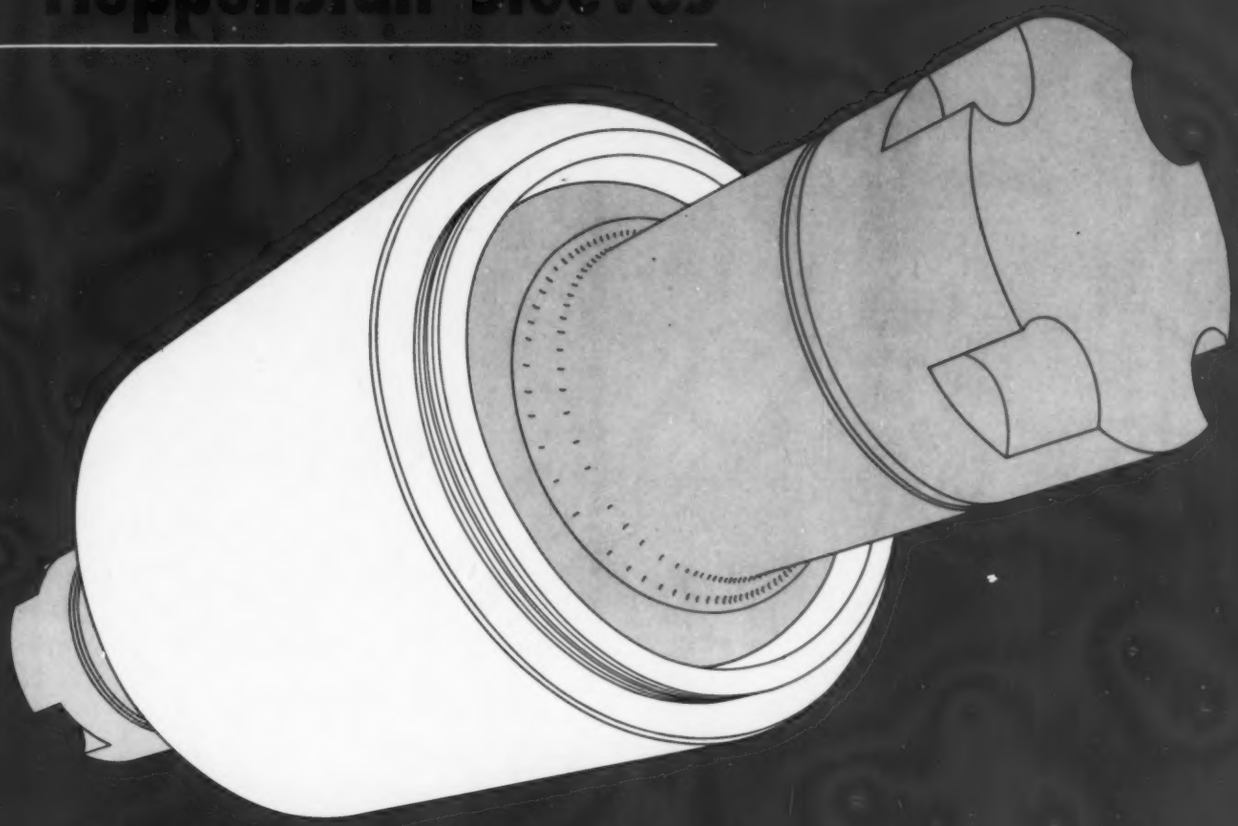
San Francisco • Seattle • Syracuse • Tampa • Tulsa • Washington, D. C.

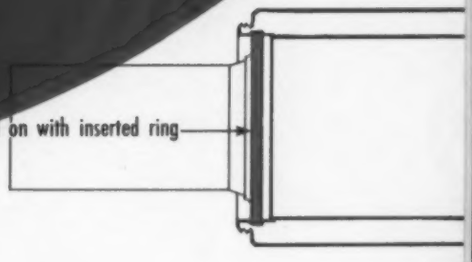
RELIANCE A-C D-C MOTORS

Heppenstall Sleeves



put back-up roll costs

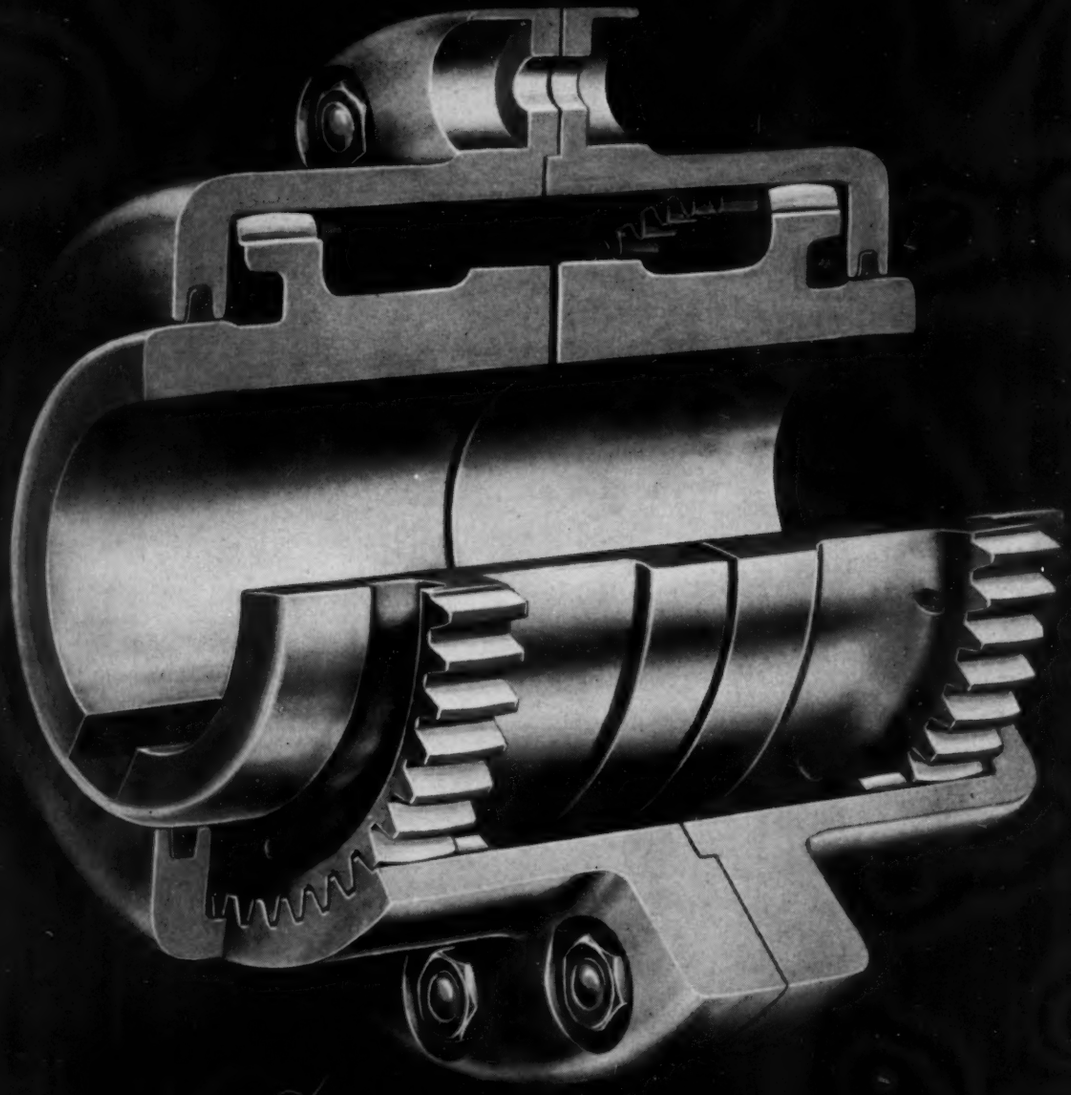
where they belong



Why scrap a worn back-up roll? Why pay for a solid one when a Heppenstall Sleeve will outwear it? Being a relatively small mass of metal without the necessity of compromising between strength of necks and hardness of surface, Heppenstall Sleeves permit the incorporation of all Heppenstall's skill in metallurgy, forging and heat treating. These sound arguments you may even disregard but you can't dismiss the 16 years of remarkable service records established by Heppenstall Sleeves. Let us tell you the complete story. Heppenstall Company, Pittsburgh, Pa.

the most dependable name in forgings—**Heppenstall**

POOLE



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY

WOODBERRY, BALTIMORE, MD.

Heavy-Duty Safety Switches and Circuit-Breaker Pylets

BUILT FOR MILL AND RAILROAD SERVICE

Pyle-National safety switches have the substantial construction needed to withstand severe operating conditions. The case and cover are heavy-section galvanized cast iron; operating parts are of heavy cast metal, and are designed for quick make and break action. Contacts are mounted on heavy slate. The operating shaft has bronze bearings. The case is fully protected, with both cover and hub plates equipped with weatherproof gaskets. The operating lever extends through the case in a rustproof bearing, and the cover is held closed by rustproof wing nuts and bolts. These features assure dependable service and long life even under severe operating conditions.

Circuit breaker Pylets are of similar heavy duty construction, and are available with or without interlocking receptacle for QuelArc plugs.

Write for Pylet general Catalog 1100 with complete listings.

PYLE-NATIONAL
ELECTRICAL EQUIPMENT
• SINCE 1897 •

THE PYLE-NATIONAL COMPANY
1334-58 North Kostner Avenue
Chicago 51, Illinois
Offices: New York, Baltimore, Pittsburgh, St. Louis, St. Paul, San Francisco

CONDUIT FITTINGS • FLOODLIGHT PROJECTORS

LOCOMOTIVE ELECTRICAL EQUIPMENT

LOOK TO THE FUSE LEADER FOR PRODUCTION PROGRESS

WARE HI-LAG *Renewable* FUSES

The Fuse That Science Built Cool to Prevent Excessive Heating During Heavy Current Loads and Long Service

When you make that next fuse installation, consider the World's Best and Coolest Operating Fuse—try WARE HI-LAG.

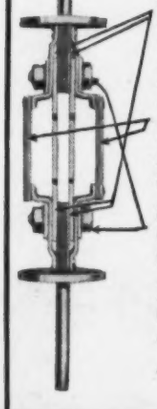
You will then see for yourself how the WARE HI-LAG stays cool under conditions that ordinarily cause overheating—you will see why it's good business to standardize on a product that ends costly delays—needless production shut downs and interruptions.

There's higher lag for motor starting overloads—stronger lag for operating current surges—lower contact resistance, reduced heating and larger and stronger terminal connections.

The double-bridge assembly at left is another cool construction feature, helping to lower contact resistance and excessive heating.

Write for Brochure giving details of all the COOL FACTS, sizes and prices.

Cool Facts No. 2



DOUBLE BRIDGE ASSEMBLY

Spring tension, double contact area on link.

Links centered in all casings.

Double Fibre Bridge for Alignment and Strength.

Screws Locked—Only one wrench needed.

Insert either end in Casing. Minimum of parts.

APPROVED BY UNDERWRITERS' LABORATORIES

WARE *Brothers* 4450 W. LAKE ST. · · CHICAGO 24, ILL.

Save Money Three Ways with Wagner EXPLOSION-PROOF MOTORS on those hazardous-location motor drives

YOU save three ways when you install Wagner type HP Explosion-Proof Motors in hazardous locations:

1. You save on engineering and construction costs because Wagner type HP motors can operate in explosive atmospheres with perfect safety, so there's no need for special vaults to house the motors, and you avoid troublesome remote-drive arrangements for delivering power from outside the hazardous area.

2. You save on maintenance costs because Wagner explosion-proof motors are totally-enclosed fan-cooled—the vital parts of the motor are sealed against the entrance of dust, fumes, and moisture which are the cause of most motor maintenance.

3. You save on insurance costs because when you use Wagner explosion-proof motors on those hazardous-location drives your plant has the best in electrical safety. Wagner type HP motors have been approved by the Underwriters' Laboratories for Class I Group D hazardous locations where gasoline, petroleum, naphtha, alcohols, acetone, lacquer solvent vapors, or natural gas are manufactured, used, or handled.

Wagner type HP Explosion-Proof motors are varied electrically to meet a wide variety of application requirements. For a complete description of the type HP, as well as all other types of Wagner motors, ask for Bulletin MU-185, and address your request to Wagner Electric Corporation, 6483 Plymouth Avenue, St. Louis 14, Mo.

These Construction Features Assure Dependability and Long Life

It's one thing for a motor to be explosion-proof; it's another thing for a motor to give dependable service over many years.

Wagner type HP explosion-proof motors are dependable and long lived — and here are a few of the many reasons why:

1. CAST ALUMINUM ROTORS
One-piece construction of aluminum which does not crystalize or become brittle when subjected to heating during overload—thus the cause of many rotor burnouts is eliminated in Wagner type HP motors.

2. CARTRIDGE BEARINGS
Cartridge construction completely seals and protects the bearings even on removal of the rotor assembly. Bearings are of liberal size.

3. ALLOY-STEEL SHAFT
Shaft is of special alloy steel which increases factor of safety under abnormal load.

4. THOROUGHLY-INSULATED WINDINGS
The stator windings are thoroughly insulated with liberal quantities of the highest-quality materials.

5. STEEL FRAME
The stator frame and feet are fabricated of heavy steel—unbreakable even under severe strains. The frame and feet are welded into one integral unit—no parts to work loose and cause trouble.

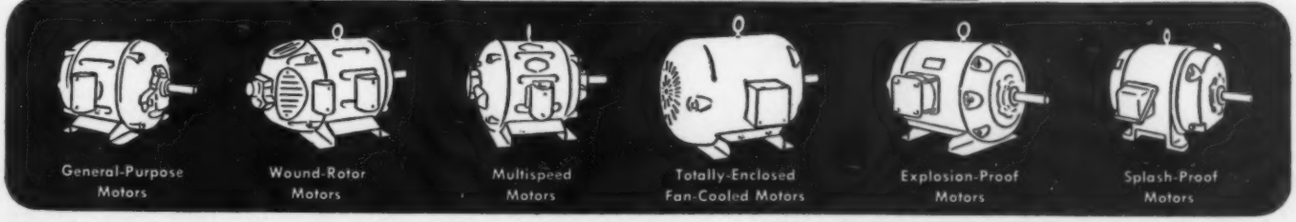
M46-5

Consult Wagner Engineers on all Electric Motor Problems

Electric Motors • Air Brakes • Brake Lining Hydraulic Brakes

Wagner

Transformers • Industrial Braking Systems NoRoL • Tachograph



Sales and Service Branches: ATLANTA 3 • BALTIMORE 18 • BOSTON 15 • BUFFALO 8 • CHICAGO 16 • CINCINNATI 10 • CLEVELAND 15 • DALLAS 1 • DENVER 2 • DETROIT 2 HOUSTON 2 • INDIANAPOLIS 4 • KANSAS CITY 8 • LOS ANGELES 15 • MEMPHIS 3 • MILWAUKEE 2 • MINNEAPOLIS 4 • NEW YORK 7 • OMAHA 2 • PHILADELPHIA 8 • PITTSBURGH 13 • PORTLAND 9 • ST. LOUIS 3 • SALT LAKE CITY 1 • SAN FRANCISCO 3 • SEATTLE 4 • SYRACUSE 2 • TULSA 3 • WASHINGTON 5 • *In Canada:* WAGNER ELECTRIC AT LEASIDE, ONTARIO—*Wagner motor parts are available at 350 Wagner-owned and -contract repair shops.*

"I Found 8 Words of Magic Power In This Ad!"

Let me cut your handling costs in HALF!
8000 lbs.
8000 lbs.
HAUS ANYTHING AND EVERYTHING FOR EVERY KIND OF BUSINESS
Transporter

"They *REALLY CUT* my handling costs!"

"The words that caught my eye were 'Let me cut your handling costs in half!' I never paid much attention to material handling . . . except I knew in round figures about what it cost us to have a lot of truckers push, pull and tug our hand-trucked loads around the plant. It was something the boys in the plant handled, definitely not a pressing problem for management. At least, so I thought, until . . .

"The coupon I skeptically mailed brought an A.T.C. Specialist around to take a look at what we were hauling. It didn't take him long to show me that what we had put down as 'fixed expense' could be turned into 'fixed profit,' simply through the use of a miracle electric truck all industry knows as Automatic Transporter.

"It's a brawny truck all right, and it sure reduces the need for brawn in our plant. One man or girl just guides and steers two to three tons with a nonchalant grasp of a handle, and the push of a button. Two of our three truckers now are doing more productive work. And everybody's happier. Management, because we've cut our handling costs in half. Labor, because it lightens their load, lets them work like men."

Put those 8 words of magic power to work for you in your plant. Mail the coupon.

Remember: Only AUTOMATIC Makes the TRANSPORTER

Transporter
A PRODUCT OF AUTOMATIC
Lightens LIFE'S LOADS

AUTOMATIC TRANSPORTATION CO.
Div. of The Yale & Towne Mfg. Co.,
47 West 87th Street, Dept. D, Chicago 20, Ill.

☐ Please mail me, without cost or obligation, complete facts about AUTOMATIC TRANSPORTER, the Miracle Electric Truck . . . plus *proof* that it has cut handling costs at least in half.

☐ Have an A.T.C. Material Handling Specialist call.

Company Name.....

By..... .....*Position*.....

Street Address.....

City.....*State*.....

United FACILITIES

Pittsburgh, Pa.
Machine Shops

Vandergrift, Pa.
Foundries and Roll
Finishing Shops

New Castle, Pa.
Foundries and
Machine Shops

Youngstown, Ohio
Machine Shops

Canton, Ohio
Foundries and Roll
Finishing Shops

Adamson United Co.
Akron, Ohio
Builders of Rubber and
Plastics Processing
Machinery

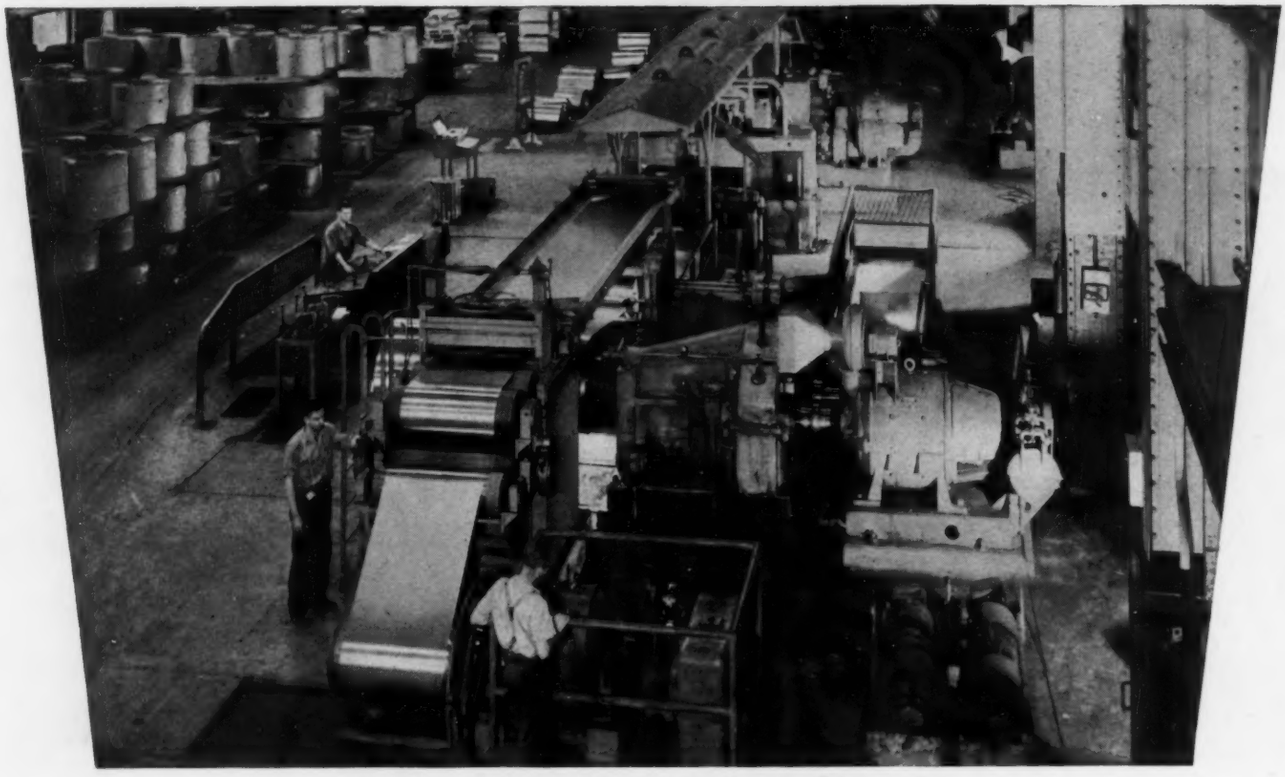
Serving the Ferrous and Non-Ferrous Rolling Industries.... and Manufacturers of Rubber, Synthetics and Plastics.

In addition to the manufacturing advantages these six great plants afford, UNITED offers the services of a corps of trained and experienced engineers, each one a specialist in his particular field. Available also are a staff of skilled metallurgists . . . a well equipped research and development department . . . an electrical engineering division . . . a roll design department, manned by experienced roll men with actual shop experience . . . a gear department . . . a department for mill operation . . . an erection and installation department . . . and a thoroughly experienced service organization. All are at your disposal for the creation, design and production of conventional, or of special processes or machinery to meet unusual requirements.

It will be worth your while to investigate our capacity and ability to serve you. There is no obligation.

UNITED
ENGINEERING AND FOUNDRY COMPANY
PITTSBURGH, PA.

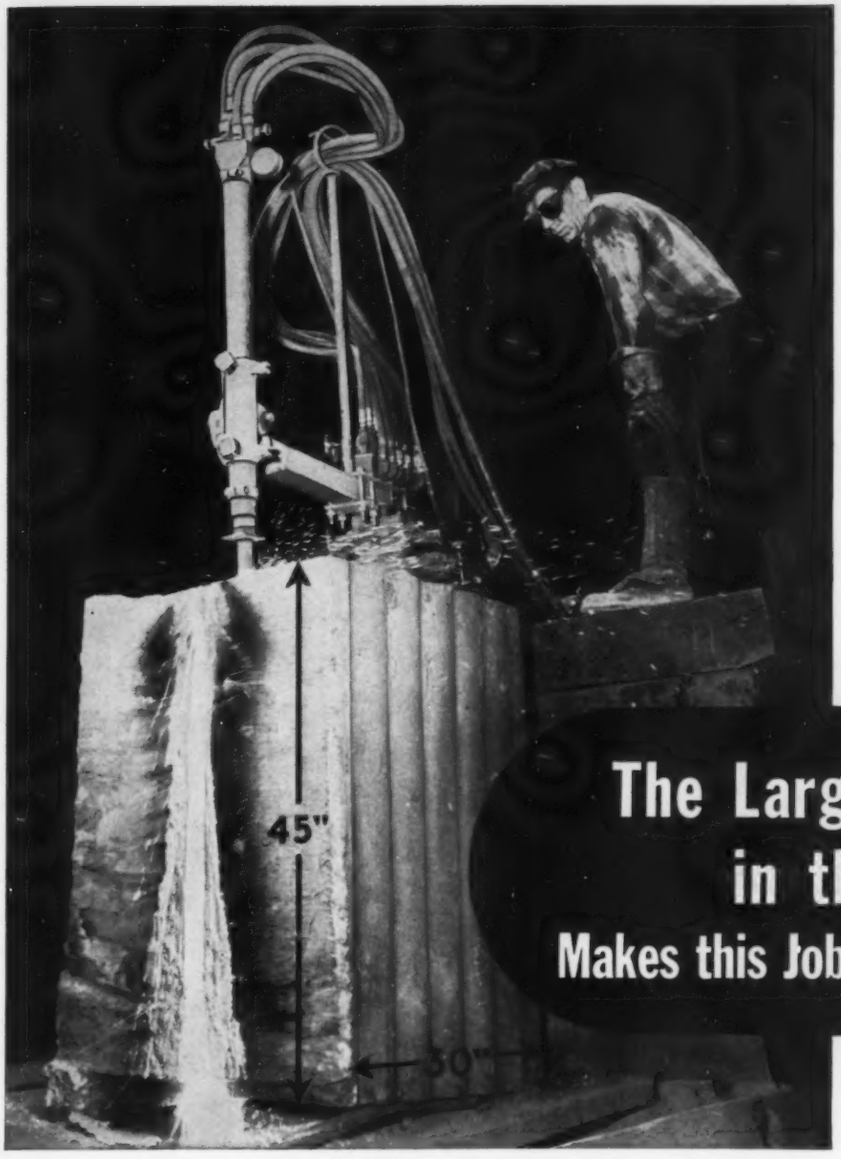
The World's Largest Designers and Makers of Rolls and Rolling Mill Equipment



● *Built by* RELIANCE ELECTRIC & ENGINEERING CO.

FROM ZERO TO 1900 FPM

The smooth performance of the Reliance Motor-drive on the exit end of this variable-voltage, side-trimming line is not jeopardized by bearing trouble. For SKF Bearings help it to provide a full range of linear speeds, from low threading and inspection speeds to a maximum production speed of 1900 feet per minute. Motor life is extended. Armatures are properly aligned. The initial air gap is maintained indefinitely. Maintenance costs are drastically reduced. Put all these advantages together, and you can easily see why it's so important to put the right bearing in the right place. 6079



The Largest Blowpipe in the World Makes this Job as Easy as it Looks

It takes just **15 minutes** to slice through an ingot of this size. For eight hours a day, five days a week, this giant OXWELD C-45 oxy-acetylene blowpipe and another just like it are in operation at this mill slitting ingots for scrap.

IF YOU CAN USE A RAPID METAL-CUTTING METHOD...

If a fast, economical method for cutting heavy ingots, risers, or forgings, will increase efficiency of operations in your plant, get in touch with the nearest Linde representative. He will help you to determine if your job can be done better by methods developed by The Linde Air Products Company.

THE LINDE AIR PRODUCTS COMPANY

Unit of Union Carbide and Carbon Corporation

30 E. 42nd St., New York 17, N. Y. UCC **Offices in Other Principal Cities**

In Canada: Dominion Oxygen Company, Limited, Toronto

LINDE OXYGEN

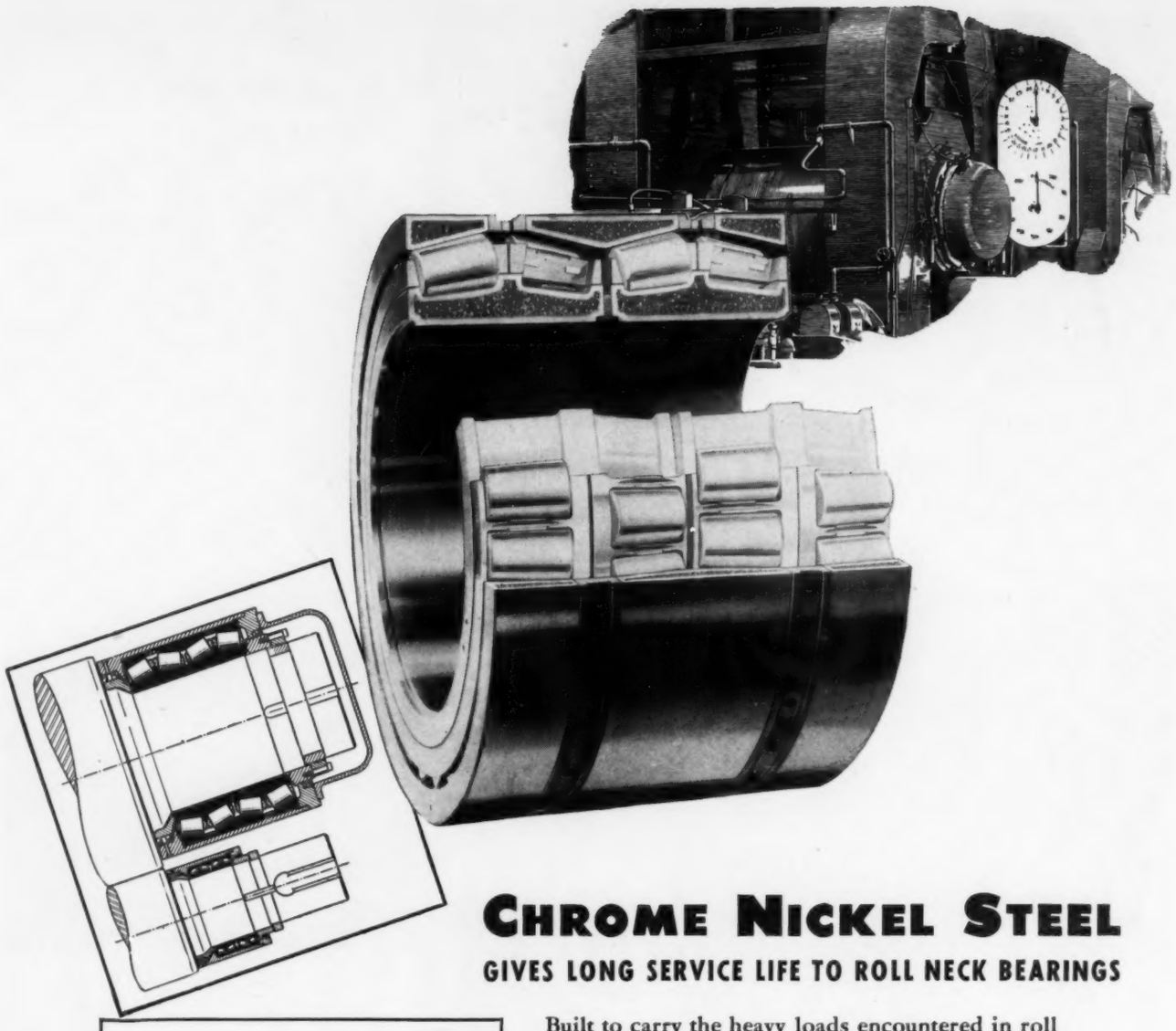
PREST-O-LITE ACETYLENE

UNION CARBIDE

OXWELD, PUROX, PREST-O-WELD, UNIONMELT APPARATUS

OXWELD AND UNIONMELT SUPPLIES

The words "Linde," "Oxweld," "Prest-O-Lite," "Prest-O-Weld," "Purox," "Union," and "Unionmelt" are trade-marks of Union Carbide and Carbon Corporation or its Units.



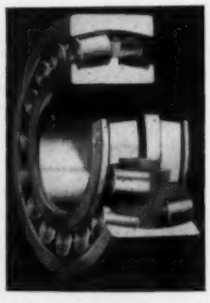
CHROME NICKEL STEEL

GIVES LONG SERVICE LIFE TO ROLL NECK BEARINGS

Built to carry the heavy loads encountered in roll neck applications, Torrington four-row tapered roller bearings provide the anti-friction means that help to pile up tonnage records and lower costs. Made of S.A.E.—3310 steel (with higher nickel content) for maximum service life, these bearings have the additional advantages of simplicity of design and a lubricating system that is controlled within the bearing itself.

Today, Torrington Bearings are also meeting anti-friction requirements in screw downs, edgers, table rolls, shears, drives, pinion stands and many other steel mill applications. Profit by Torrington's specialized knowledge and wide experience by specifying Torrington Bearings when you order equipment.

THE TORRINGTON SELF-ALIGNING SPHERICAL ROLLER BEARING



This Self-Aligning Spherical Roller Bearing is manufactured as a complete unit for easy handling and installation, and will be available in a full range of sizes from 1.5748" bore and up. Write for further information or consult your nearest Torrington Representative.

THE TORRINGTON COMPANY • BANTAM BEARINGS DIVISION
SOUTH BEND 21, INDIANA

TORRINGTON BEARINGS

SPHERICAL ROLLER • STRAIGHT ROLLER • TAPERED ROLLER • NEEDLE • BALL

How BAILEY CONTROLS Improve Power Service

IN YOUR PLANT

There may be opportunities for the improvement of power service as well as for increasing safety, saving fuel and reducing maintenance by the proper application of Bailey Controls. Get the recommendation of your local Bailey Engineer or write for Bulletin 15-C describing Bailey Controls for Steam Plants. Bailey Meter Company, 1047 Ivanhoe Road, Cleveland 10, Ohio. In Canada—Bailey Meter Company Limited, Montreal.

A-94

CONTINUITY

Fewer outages of boilers and prime movers improve continuity of power service.

CAPACITY

In addition to increasing steam generating capacity Bailey Controls also increase output and efficiency of prime movers by supplying steam at design conditions.

HEAVY LOAD SWINGS

Simultaneous regulation at all points of control accurately and safely takes the boiler through heavy load swings.

PROCESS STEAM

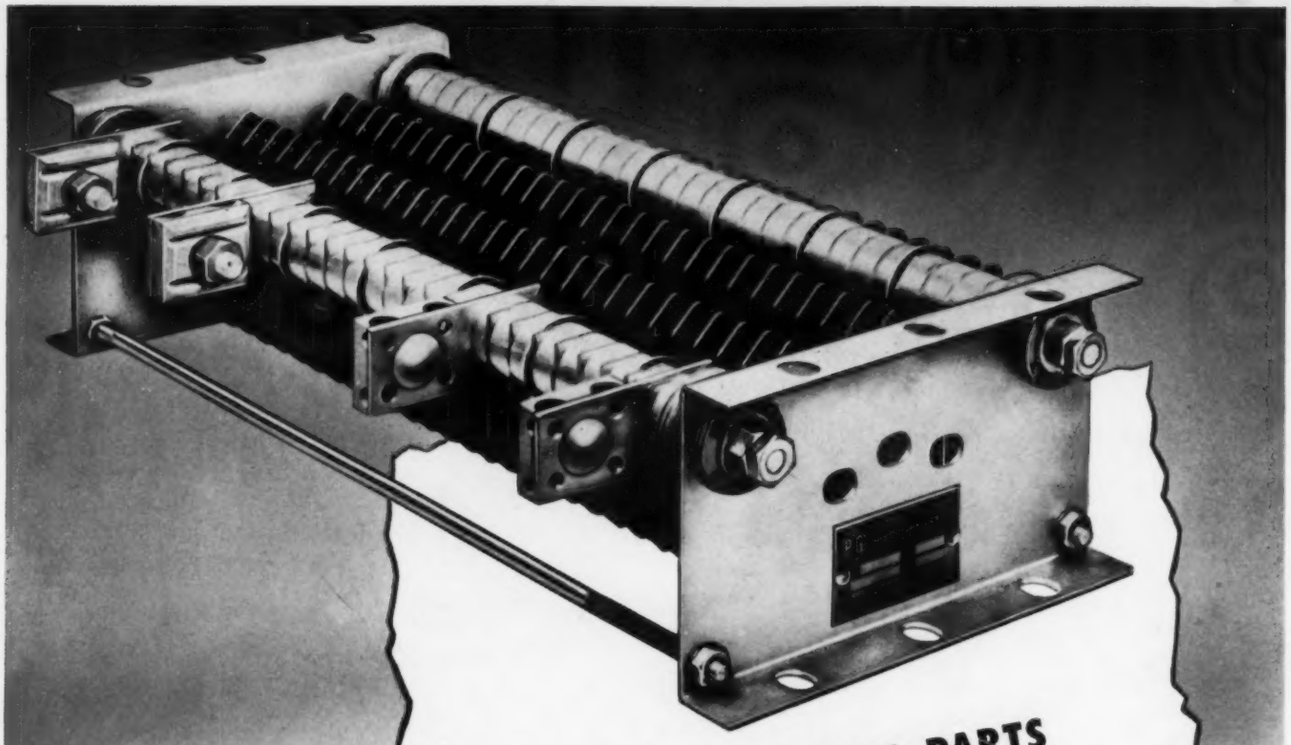
Steam at correct pressures and temperatures for process operation is furnished by combustion and steam temperature controls. Pressure reducing and desuperheating control systems insure adequate low pressure steam. Combustion control usually does away with the need for a steam accumulator.

BAILEY METER COMPANY

1047 IVANHOE ROAD · · · CLEVELAND 10, OHIO

Controls for Steam Plants

COMBUSTION • PRESSURE
FEED WATER • LIQUID LEVEL
TEMPERATURE • FEED PUMPS



REDUCE INVENTORIES OF MAINTENANCE PARTS

. . . with P-G *Steel Grid Resistors* . . .

Post-Glover Standard Resistor Units, of identical dimensions, are produced in a wide variety of resistance values and capacities.

In combination, they give complete resistor values for practically any motor control desired.

Because comparatively few types are necessary in the supply room, maintenance repairs are made with the utmost speed and a minimum investment.

A P-G sales engineer will be glad to explain . . . in detail . . . how you can save with the Nonbreakable Steel Grid Resistor.

ALL STEEL CONSTRUCTION
MICA INSULATION
RUGGED TERMINALS
PROVISION FOR EXPANSION
ADEQUATE VENTILATION
UNAFFECTED BY VIBRATION
MOISTURE RESISTANT
CORROSION PROTECTED

Write for Bulletin No. 500

P-G

The Nonbreakable Steel Grid Resistor

THE POST-GLOVER ELECTRIC COMPANY

• ESTABLISHED 1892 •

221 WEST THIRD STREET, CINCINNATI 2, OHIO

From End to End of Power Piping Uniform Quality Stands Guard

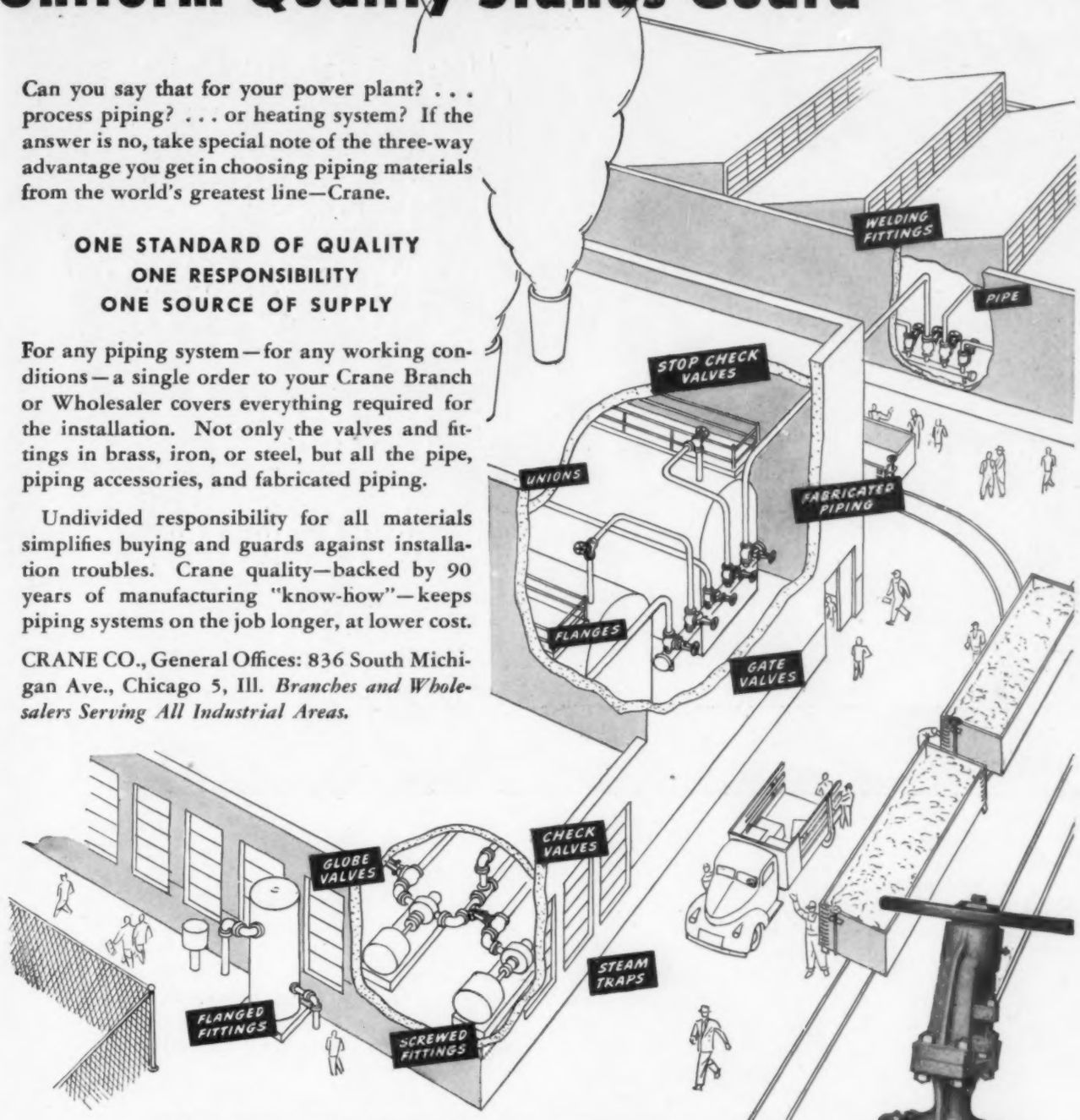
Can you say that for your power plant? . . . process piping? . . . or heating system? If the answer is no, take special note of the three-way advantage you get in choosing piping materials from the world's greatest line—Crane.

ONE STANDARD OF QUALITY
ONE RESPONSIBILITY
ONE SOURCE OF SUPPLY

For any piping system—for any working conditions—a single order to your Crane Branch or Wholesaler covers everything required for the installation. Not only the valves and fittings in brass, iron, or steel, but all the pipe, piping accessories, and fabricated piping.

Undivided responsibility for all materials simplifies buying and guards against installation troubles. Crane quality—backed by 90 years of manufacturing "know-how"—keeps piping systems on the job longer, at lower cost.

CRANE CO., General Offices: 836 South Michigan Ave., Chicago 5, Ill. *Branches and Wholesalers Serving All Industrial Areas.*



(*Right*) Typical of the uniformly high quality in Crane products—Crane Alloy Steel Wedge Gate Valves. The 600-pound class, with Exelloy to No. 49 Nickel Alloy seating, is recommended for steam, water, gas or air up to 850° F. maximum; with Stellite to Stellite, for steam up to 1000° F.; with Exelloy to Exelloy, for oil or oil vapor up to 1100° F. Screwed, flanged, or welding ends. See your Crane Catalog for complete specifications.

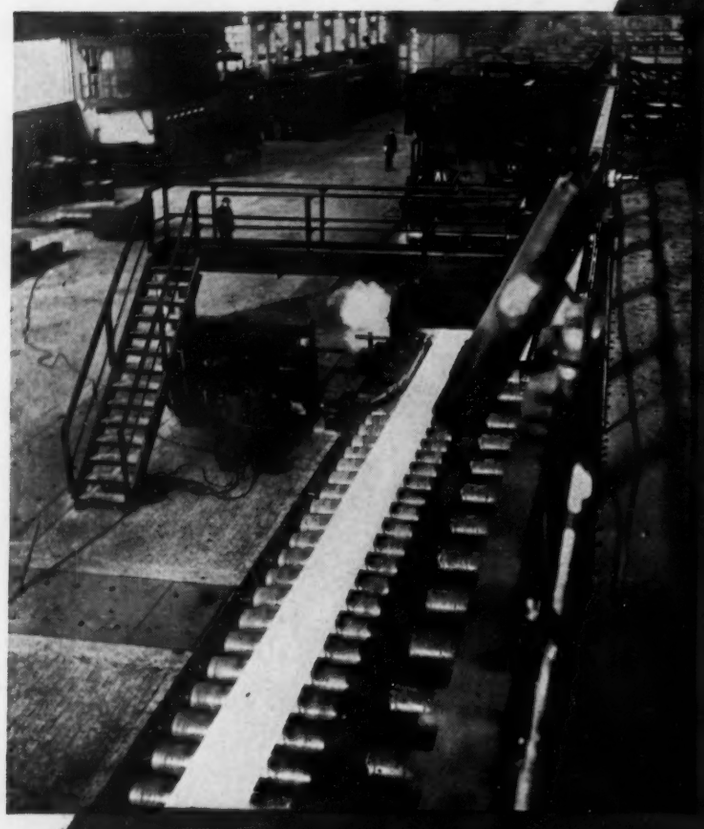
EVERYTHING FROM . . .

VALVES • FITTINGS
PIPE • PLUMBING
HEATING • PUMPS

CRANE

FOR EVERY PIPING SYSTEM

Protect your gear drives...



Use lubricants that...

1. RESIST THICKENING
2. CARRY MAXIMUM LOADS

GEARS and bearings of steel mill reduction drives operate more efficiently, and last longer with Texaco Meropa Lubricants. Here's why—

Texaco Meropa Lubricants are made especially to withstand the shock loads and enormous pressures experienced in the heaviest service. Oxidation stability and resistance to thickening are very high, and load-carrying capacity is more than ample to protect any gear. Moreover, Texaco Meropa Lubricants cling to the gears, do not separate in use or in storage, and are non-corrosive to bearing metals.

You'll get excellent results with Meropa, too, on coiler, edger roll, slab shear and run-out drives, table manipulator gears, and many other places where heavy load presents a lubricating problem.

Meropa Lubricants were developed by Texaco research, working in cooperation with leading gear manufacturers and steel mill operators. Over the years, Meropa has been steadily improved to keep pace with advances in machinery design, and are available today in a complete line to meet all heavy-duty gear drive requirements. You will find them in service everywhere.

Call freely on Texaco Lubrication Engineering Service. Simply contact the nearest of the more than 2300 Texaco distributing plants in the 48 States, or write: The Texas Company, 135 East 42nd Street, New York 17, N. Y.

TEXACO

TEXACO Meropa Lubricants

FOR STEEL MILL REDUCTION GEARS

TUNE IN THE TEXACO STAR THEATRE EVERY SUNDAY NIGHT STARRING JAMES MELTON WITH HIS GUEST, ED WYNN — CBS

REDUCE THE FRICTION COEFFICIENT OF YOUR ROLLS WITH N·B·M BEARINGS

These easy-rolling new Mill Bearings have a remarkably low coefficient of friction—and retain their efficiency far longer than conventional types. That means less power wasted—less strain on motors—less maintenance costs... *Plus:*

- 10 to 18 times longer service • Far greater tonnage
- Freedom from cut roll necks • Substantial savings in power and maintenance costs.

Our engineers will gladly show you actual case histories—write us today.

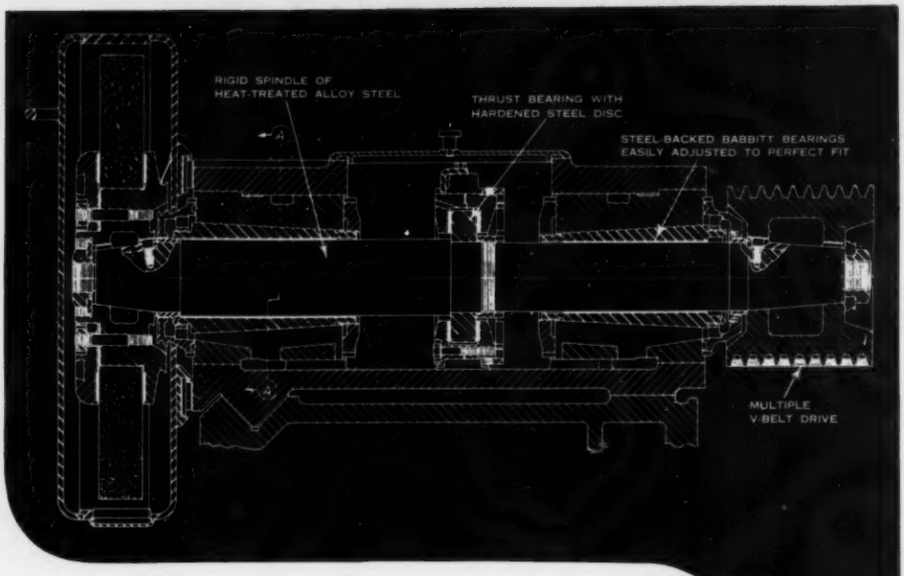
N·B·M
BRONZE AND COPPER CASTINGS

Blast Furnace Copper Castings • Roll Neck Bearings
Slippers • Housing Nuts • Machinery Castings • Babbitt Metals • Acid Resisting Castings • Phosphorized Copper

NBM
NATIONAL BEARING
DIVISION
PITTSBURGH • NEW YORK
AMERICAN Brake Shoe COMPANY

PLANTS IN: ST. LOUIS, MO. • PITTSBURGH, PA. • MEADVILLE, PA. • JERSEY CITY, N. J. • PORTSMOUTH, VA. • ST. PAUL, MINN. • CHICAGO, ILL.

WHAT gives a FARREL Roll Grinder its PRECISIONABILITY?


RIGID SPINDLE OF HEAT-TREATED ALLOY STEEL
THRUST BEARING WITH HARDENED STEEL DISC
STEEL-BACKED BABBITT BEARINGS EASILY ADJUSTED TO PERFECT FIT
MULTIPLE V-BELT DRIVE

One of the main reasons for a Farrel roll grinder's outstanding ability to produce fine precision work is the construction and mounting of the grinding wheel spindle. Careful engineering and precise workmanship at this vital point pay off in the flawless mirror finish that can be produced consecutively on any number of rolls.

The spindle itself is of large diameter to assure rigidity under working load. It is made of high grade alloy steel, carefully machined, heat-treated and finally ground to extremely close limits.

The spindle is mounted in tapered, babbitt-lined, steel-backed bearings which are split longitudinally, and fitted with a locking wedge. Running clearance is easily controlled by adjusting collars at both ends of each bearing. Bearings are precision finished to assure perfect fit and alignment.

Thrust is taken by a hardened steel disc and two babbitted rings at the center of the spindle. This permits free expansion of the spindle bearings and insures less deflection of the spindle than would occur if the thrust bearing were at the end.

The spindle is driven by multiple V-belts, which operate with little tension, permitting closer clearance in the spindle bearings and consequently producing greater accuracy in the work.

If you have a roll grinding problem where accuracy of finish is vital, write for complete detailed information about Farrel roll grinders, either type TT (traveling work table) or type HD (heavy duty). No obligation.

FARREL-BIRMINGHAM COMPANY, INC.
ANSONIA, CONNECTICUT

Plants: Ansonia, Derby and Stonington, Conn., Buffalo, N. Y.
Sales Offices: Ansonia, Buffalo, New York, Pittsburgh, Akron, Los Angeles, Tulsa, Houston, Charlotte

FB-303

Farrel-Birmingham

LIGHTWEIGHT CRATE **made entirely of standard mill forms of Monel. End doors are equipped with handy locking mechanism. Of welded construction, it was fabricated by *The Youngstown Welding & Engineering Company* for use by a prominent bearing manufacturer.**

HERE'S a rugged crate of simple design.

Note the end-door construction. Unloading the 6-tons of forged steel rings handled in this crate is easy . . . and fast.

Made of Monel* by *The Youngstown Welding & Engineering Company,* Youngstown, Ohio, for a prominent bearing manufacturer, the crate is almost 12 feet long, 2½ feet wide and 3 feet deep.

There's plenty of strength, toughness and corrosion resistance in Monel. Hot-rolled bar, for example, has a tensile strength of 80-95,000 psi. And sulfuric acid and other commonly used pickling solutions won't sap its strength in a hurry. That's why you can use lightweight sections. You don't have to make your equipment heavy or bulky to allow for rapid corrosion.

Only standard mill forms of Monel were needed for construction of this crate. (That's one of the *many* good things about Monel. You can almost always save money by using easily obtained Monel rod, bar, sheet, strip or plate.)

In any form, Monel is easy to fabricate. It is readily bent and cut. It can be machined when necessary . . . and riveted, brazed or welded.

Monel will last for years in your pickling room. When your crates, racks, baskets, hooks, chain and accessories are Monel, you have tough, light, *safe* equipment. You handle bigger loads . . . *faster,* and with less expense for acid, labor and maintenance.

*Reg. U. S. Pat. Off.

Monel

THE INTERNATIONAL NICKEL COMPANY, INC., 67 Wall Street, New York 5, N.Y

TRIAL BY FIRE

Regardless of their origin, fires often travel along electrical cables, spreading damage to other locations, interrupting production schedules. Okolite-Okoprene cables, however, do not support combustion.

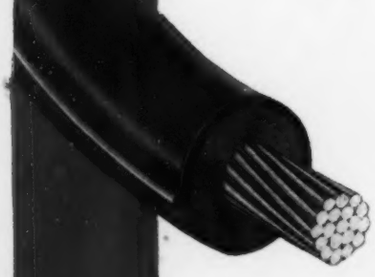
TRIAL BY ACID

Indoors or underground, electric cable life is frequently shortened by the corrosive bite of acids used in processing operations. Okolite-Okoprene cables resist the attack of commonly-used industrial chemicals.

—AND NOW TRIAL BY YOU

MOISTURE

The steady assault of moisture — outdoors or condensed in conduits — eventually ruins many cable insulations. Cables insulated with Okolite-Okoprene retain their electrical stability even when totally immersed.



If you're not already using Okolite-Okoprene* cables, actual use in your own plant should confirm your selection. Millions of feet of Okolite-Okoprene — in every type of industrial service — have established their long life and low maintenance — those *lasting values* that are more important than ever today.

And keep in mind these *other facts* about Okolite-Okoprene cables . . . no braids to rot . . . oil-resistant . . . unaffected by sunlight and extremes of hot and cold weather . . . high temperature operation (75°C). Write for your copy of fact-filled bulletin OK-2009C. The Okonite Company, Passaic, N. J.

*U. S. Pat. No. 2,312,058

OKONITE SINCE 1878 **insulated wires and cables**

Continental

designs and builds modern, low-cost, High Speed Continuous Weld Tube Mills

Capable of high, sustained production over long periods with minimum maintenance, this rugged ½" to 4" Continental Continuous Weld Tube Mill embodies many new engineering developments and improvements.

Like all CONTINENTAL EQUIPMENT—it was designed and built to provide greater output at lower UNIT cost.

Let Continental Engineers work with you in the designing and building of your needed equipment.

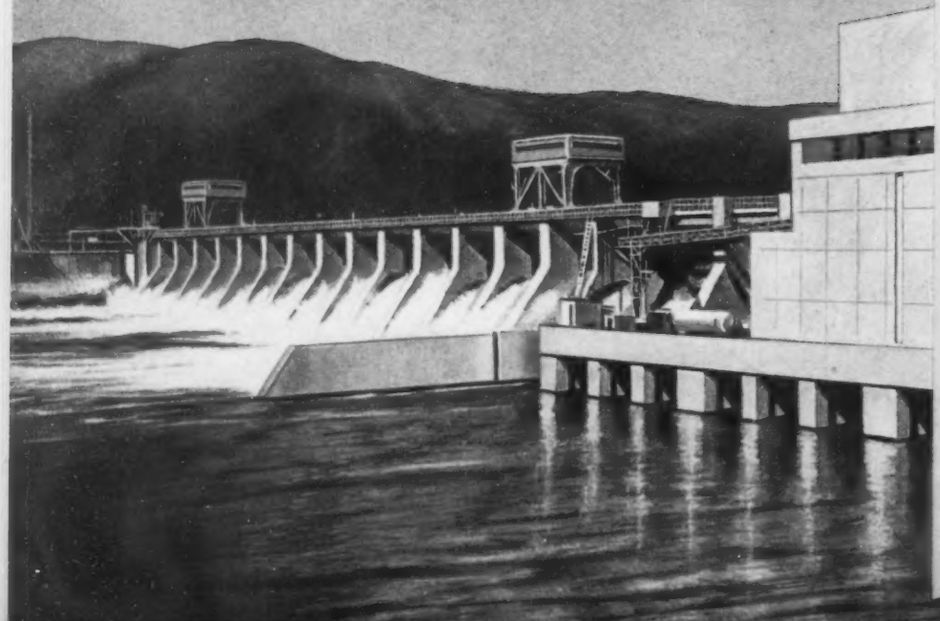
Continental

Continental

Plants at: E. Chicago, Ind. · Wheeling, W.Va. · Pittsburgh, Pa.

62,000 pound Continental Castings

FOR GIANT HYDRO-ELECTRIC OPERATION



Outstanding skill in research, design, engineering and manufacture is available for ordinary *"production line"* 50 pound castings up to difficult, unusual castings that weigh as much as 250,000 pounds.

When you need Steel Castings of any type *—call on Continental.*

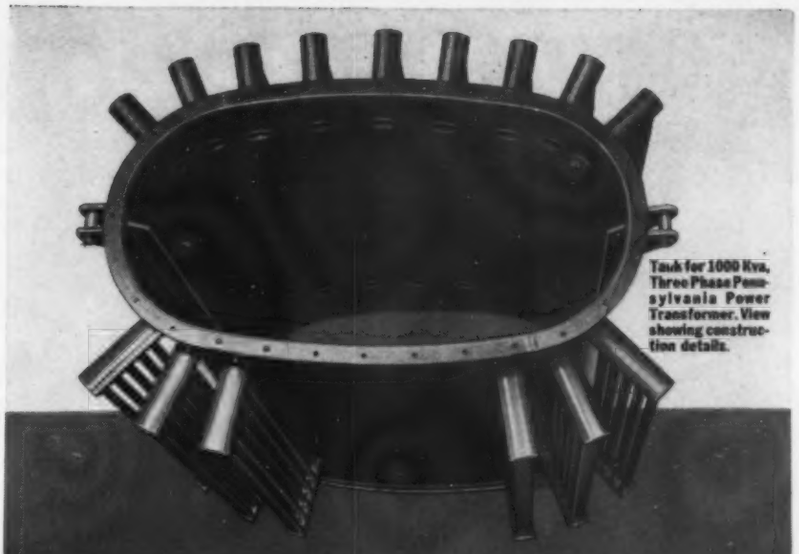
Continental

FOUNDRY & MACHINE CO.

PITTSBURGH • CHICAGO

Plants at: E. Chicago, Ind. • Wheeling, W.Va. • Pittsburgh, Pa.

Pennsylvania POWER TRANSFORMERS



Tank for 1000 Kva, Three Phase Pennsylvania Power Transformer. View showing construction details.

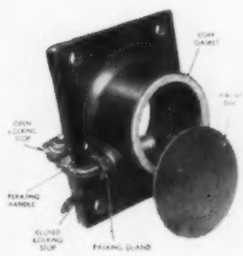
NOTE THESE

TANK and RADIATOR Construction Features

Tank Base showing welded steel

Detachable Radiator.

Radiator Valve.



THEY ASSURE . . .

- RELIABILITY
- LOW MAINTENANCE COSTS
- LONG SERVICE LIFE

1. PENNSYLVANIA POWER TRANSFORMER TANKS AND COVERS are fabricated of heavy copper-bearing steel plate, all seams arc welded with coated electrodes according to the latest standards of the American Welding Society.

2. COVERS are provided with an opening permitting access to the terminal board and to the lower end of the bushings. By means of lugs welded to the cover and an angle structure, the cover may be handled separately or as a unit with core and coil assembly.

3. LIFT LUGS, welded to the tank, are provided for handling the complete transformer with cable slings, chains or hooks.

4. GUIDE BARS, welded to the sides of the tank, extend vertically from top to bottom, permitting the core and coils to be guided into the tank and properly centered by means of guide plates on the core clamping frames, which engage the guide bars.

5. TANK BASES constructed of heavy structural steel shapes welded together and to the bottom of the tank, permit the transformer to be rolled in any direction desired.

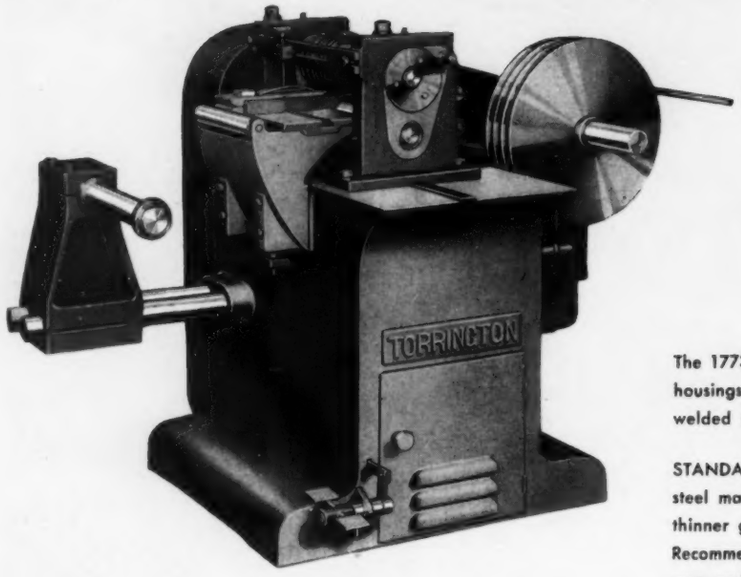
6. PENNSYLVANIA UNI-ROW RADIATORS consist of a single row of heavy gauge oval tubes, welded externally to an oval header at the top and bottom. The radiators, which are as ruggedly constructed as the tank, have a uniform cross-section throughout their length and are tested at a pressure of 100 pounds per square inch. They are spaced to readily permit shotblasting, cleaning and painting, by either brush or spray, in factory or field. The oval shape of the headers and the absence of crevices, prevent moisture from lodging on the headers and tubes. Radiators may be either permanently welded to the tank or detachable. Larger transformers are equipped with detachable radiators which may be removed to conform to shipping clearances. Transformers thus equipped are furnished with valves which permit removal of the radiators without draining oil from the transformer. Plugs and air vents are provided on each radiator for filling and draining. Detachable type radiators have lift lugs to facilitate handling.

7. SHOT BLASTING is used to clean the surface of the tank, cover and tubes, and all exposed outside surfaces are painted with one priming and two finishing coats of special, approved transformer paint.

Pennsylvania TRANSFORMER COMPANY

808 Ridge Avenue N. S., Pittsburgh 12, Pa.

A *NEW* WAREHOUSE SLITTER



The TORRINGTON WAREHOUSE METAL SLITTING MACHINE 1773*

The 1773 Warehouse Type Metal Slitting Machine is a compact unit. The housings, payoff, winder and motor drive are all mounted on a single welded steel base, reducing floor space to approximately 4' x 6'.

STANDARD CAPACITY—5 cuts (4 strips) .080" non-ferrous or .062" mild steel maximum thickness, or an equivalent number of additional cuts in thinner gauges up to 12" or 18" maximum trimmed width respectively. Recommended minimum thickness .010". Maximum O.D. of coil 20"; maximum weight of coil, 400 lbs. Special supports for heavier coils can be supplied.

SPEED—150 F. P. M.

CUTTERS AND CUTTER ARBORS—Cutters (separately quoted) are 5½" diameter, of either alloy tool steel or hi-carbon, hi-chrome steel. Arbors are of steel, 2⅝" diameter, with ½" x ½" key.

ADJUSTMENTS—An exclusive feature is a manual adjustment of the top arbor to compensate for wearing down of the cutters. Simple, manually operated spur gears rotate the eccentric arbor bushing at each housing, providing a total adjustment of 9/16".

GUIDE TABLE—At entry has adjustable side guides, wood wipers with spring to exert tension on the metal, and idle guide roller. 40" metal line.

WINDER—At exit consists of a 2½" diameter winding arbor fitted with 3/32" slot and handwheel for starting strips. Recommended maximum thickness on 2½" diameter arbor is .062".

SEPARATOR DISCS — (separately quoted) Hardened and tempered spring steel .055"—.050" thick and 14" or 20" diameter.

DRIVE—Standard make motor, 5 H.P., 1800 R.P.M. Drive to winder through Link leather belt.

In the field of warehouse metal slitting, a compact, smoothly running, well-guarded slitter is required, which above all may be quickly set up to produce any desired combination of cuts on any gauge of metal within its range.

The Torrington *1773 Warehouse Type Metal Slitting Machine has been especially designed to meet these requirements. Years of experience in building metal slitting machines have been applied to the development of this model, which was first announced at the recent National Metal Exposition. The enthusiastic reception of the 1773 has proved the desirability of the design, and enabled Torrington to commence manufacturing in production lots, which makes possible a highly competitive price.

Detailed specifications and quotation will be furnished upon request.

*The number "1773" indicates that this is the one thousand seven hundred and seventy-third complete and original design planned on the drafting boards of the Torrington Manufacturing Company. The number of machines built for the metal mills is many times that figure.

The TORRINGTON MANUFACTURING COMPANY
TORRINGTON, CONNECTICUT

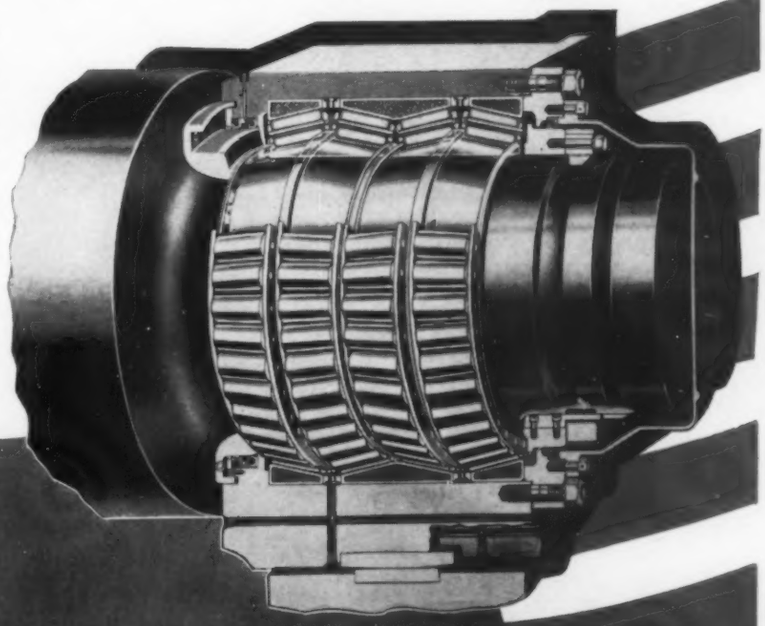
Increased Roll Neck Strength

with TIMKEN BALANCED PROPORTION BEARINGS

The demand for greater rigidity in modern rolling mills has led to the necessity for greater roll neck diameters. This trend largely was responsible for the development of Timken Balanced Proportion Roll Neck Bearings.

These bearings enable the mill builder and mill operator to take full advantage of the recognized superiority of roller bearings and at the same time be assured of adequate roll neck strength through increased roll neck diameter made possible by Timken Balanced Proportion Bearing design.

For further information consult your mill builder or our roll neck bearing engineers. The Timken Roller Bearing Company, Canton 6, Ohio.



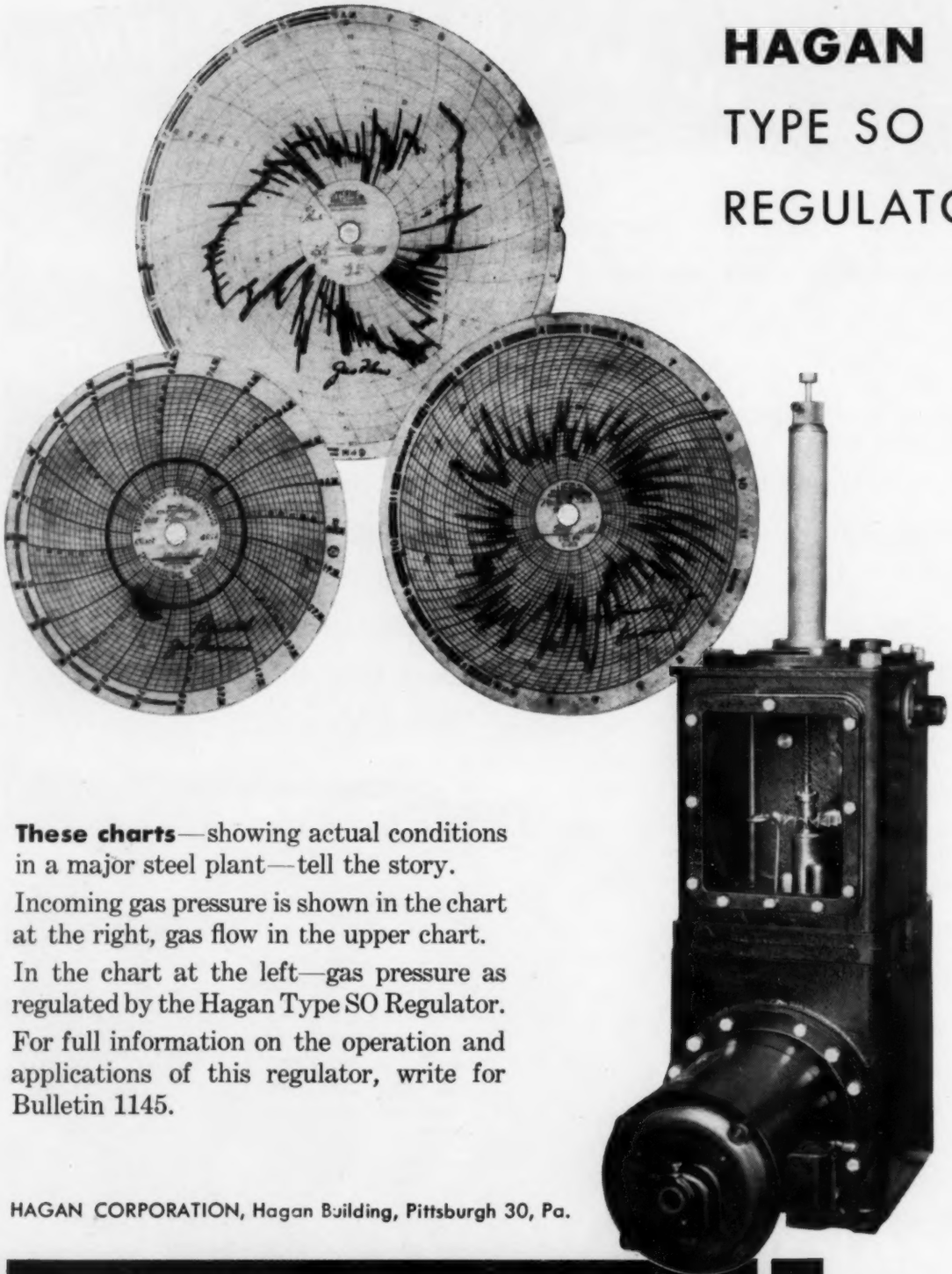
TIMKEN

TRADE-MARK REG. U. S. PAT. OFF.

ROLL NECK BEARINGS

When pressures must be kept constant—

HAGAN
TYPE SO
REGULATOR



These charts—showing actual conditions in a major steel plant—tell the story.

Incoming gas pressure is shown in the chart at the right, gas flow in the upper chart.

In the chart at the left—gas pressure as regulated by the Hagan Type SO Regulator.

For full information on the operation and applications of this regulator, write for Bulletin 1145.

HAGAN CORPORATION, Hagan Building, Pittsburgh 30, Pa.

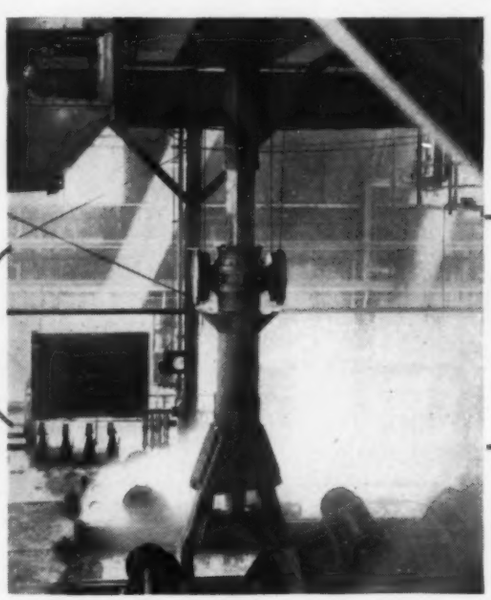
HAGAN *Automatic* COMBUSTION CONTROL
The pioneer . . . and still the leader

HAGAN
HALL
BUROMIN
CALGON

New *Alliance* Soaking Pit Crane in Action

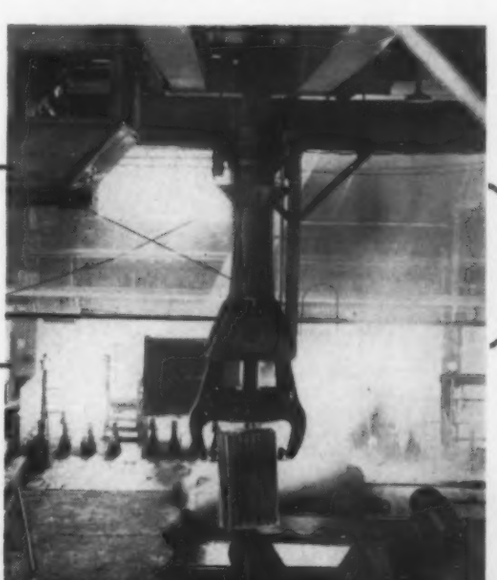
MULTIPLE RANGE TONGS

By means of an ingenious locking pin, the tongs can be adjusted, *in less than a minute,* to any one of four positions: Position (1) takes care of ingots up to 10" x 22"; position (2) — 18" x 40"; position (3) — 36" x 52"; and position (4) — 48" x 60". Maximum and minimum range can be made to suit any requirements.



HOLLOW, RECTANGULAR TELESCOPIC STIFF LEG

Telescopic • Self-Lubricating • Revolving • Flexibly Connected • Adjustable Range Tongs with Variable Intensity Grip.



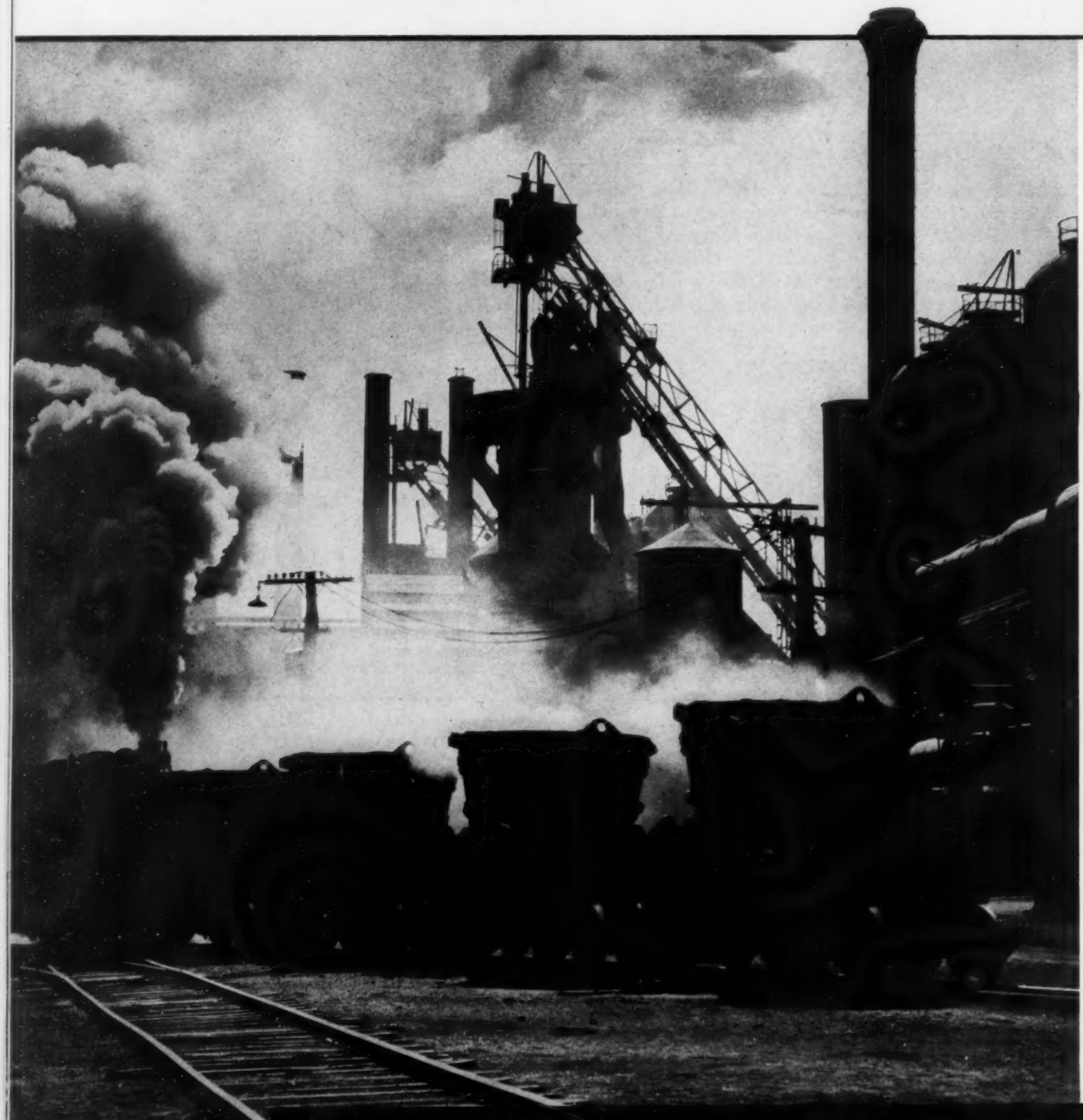
FULL VIEW OPERATION

Write to Alliance, world's largest builders of the world's largest cranes, for profitable data on this new advancement in soaking pit cranes.

THE ALLIANCE MACHINE COMPANY • ALLIANCE, OHIO

PITTSBURGH OFFICE : 1622 OLIVER BUILDING

Background for Ferrous and Non-Ferrous Industries Since 1856



ARMY NAVY

DESIGNERS AND BUILDERS OF ROLLS AND ROLLING MILL EQUIPMENT

LEWIS FOUNDRY & MACHINE

DIVISION OF BLAW-KNOX COMPANY, PITTSBURGH, PA

how would YOU tackle this job today?

Old Pharaoh called in his chief engineer.

"There's some unimproved real estate down by Gizeh. Put up a great big pyramid there so people will know I was a somebody. Don't bother me with details. Make it big—and quick!"

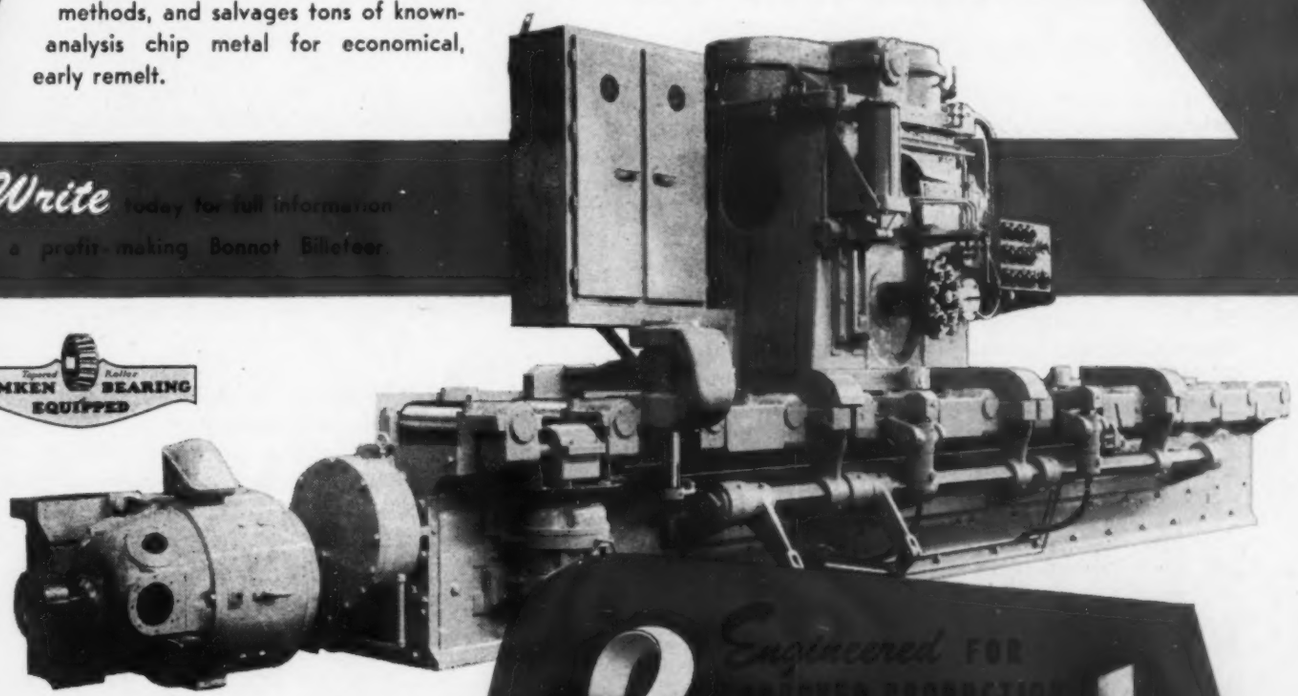
So Pharaoh's C. E. got 100,000 men and worked 20 years on that job.

Today executives expect big things, too. But they want everything cheaper — better — quicker. Fortunately for you, machinery makes it possible to meet these demands.

When it comes to billet-chipping, hand-work is unnecessarily slow and expensive. Labor that could be used to more productive advantage elsewhere in your operations is tied up in a gruelling, less-profitable job.

THE BONNOT BILLETEER, with one easily-trained operator, can chip more billets than at least TEN hard-working men using outmoded hand methods. Beyond this important saving in time, the Billeteer chips cleaner than is possible by hand, saves many billets on which cleaning cost would be prohibitive by other methods, and salvages tons of known-analysis chip metal for economical, early remelt.

Write today for full information on a profit-making Bonnot Billeteer



A MODERN MACHINE

- Reduces total cost of chipping.
- Speeds up billet chipping. . . . .
- Saves labor time and cost. . . . .
- Prevents man power fatigue. . . .
- Lowers maintenance and power cost.
- Cuts waste of valuable steel. . . .

Engineered FOR HIGHER PRODUCTION

Bonnot

THE BONNOT COMPANY
CANTON 2, OHIO

BUILDERS OF **THE BILLETEER**

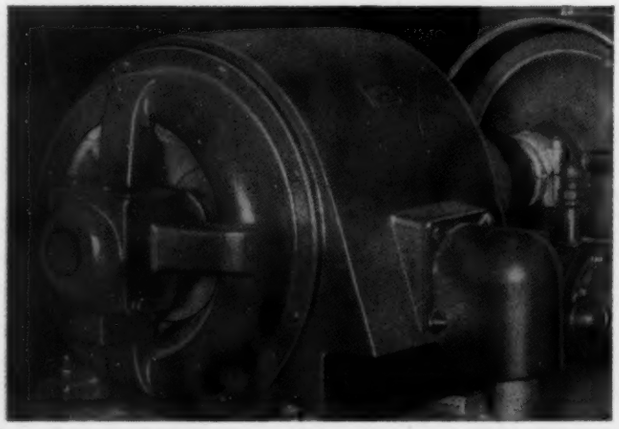
ADDRESS CORRESPONDENCE TO STEEL EQUIPMENT DIVISION

Why should steel mills use

LAMINATED PLASTIC BEARINGS?*

EWING GALLOWAY

1. Why should steel mills use laminated plastic bearings? Checks made at peak production prove that laminated plastic bearings reduce shut down periods for bearing replacement, lower power consumption, practically eliminate lubrication costs and outwear metal bearings. For example, . . .

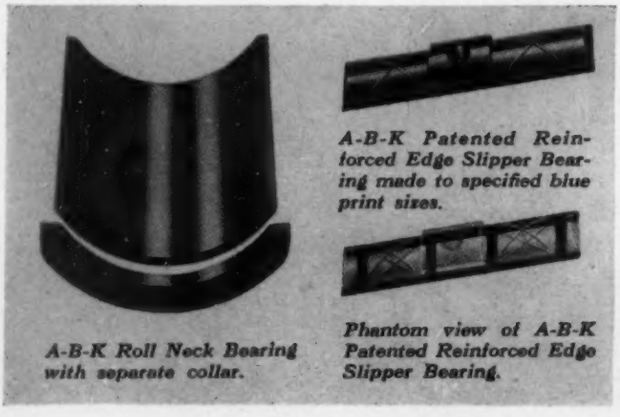


2. What reduction can be made in power consumption? Users report remarkable power savings, running to sizeable figures. Even *average* savings are surprisingly high. This is due to the hard, smooth surface of laminated plastic bearings and their exceptionally low coefficient of friction. Furthermore . . .

EWING GALLOWAY

3. How much are shut down periods for bearing replacement reduced? Laminated plastic bearings often have a life many times longer than metallic bearings. Long life without failure means fewer bearing replacements—and naturally, a substantial reduction in lost production hours. Equally important to you . . .

4. Why should you specify A-B-K Laminated Plastic Bearings? The engineering and research facilities of American Brakeblok Division, American Brake Shoe Company stand back of A-B-K Laminated Plastic Bearings. These bearings were designed for the tough jobs. They have met the severest tests of war production—are ready to serve you equally well in peace.



A-B-K Roll Neck Bearing with separate collar.

A-B-K Patented Reinforced Edge Slipper Bearing made to specified blue print sizes.

Phantom view of A-B-K Patented Reinforced Edge Slipper Bearing.

5. For full information on A-B-K Laminated Plastic Bearings and their application to your steel mill bearing problems, phone, write or wire, American Brakeblok Division, 4600 Merritt Ave., Detroit 9, Mich.

American Brakeblok

TRADE MARK REG. U.S. PAT. OFF.

***A·B·K Laminated Plastic Bearings**

Brake Shoe

AMERICAN BRAKEBLOK DIVISION
DETROIT 9, MICHIGAN

"AFTER 14 YEARS OF SERVICE OUR *Baker Truck* NEEDS NO NEW PARTS!"

"Your letter of December 29 was received with relation to our Baker Truck. Our superintendent tells us that surprising as it may seem, no new parts are necessary. Your representative told him what adjustments could be made, and it seems that they could do it all right there at the cannery. It looks like this is just one more blue ribbon for the Baker Truck, because it is amazing that after all these years of service a general replacement of essential parts is unnecessary. It is certainly very gratifying to us."

—And gratifying to us, too! Letters like the above, from a food processing plant, prove two things: first, that the sturdy construction and high standards of Baker engineering design are accomplishing their objectives—dependable service and long life; second, that proper industrial truck care pays the user big dividends in continuous operation and low maintenance.

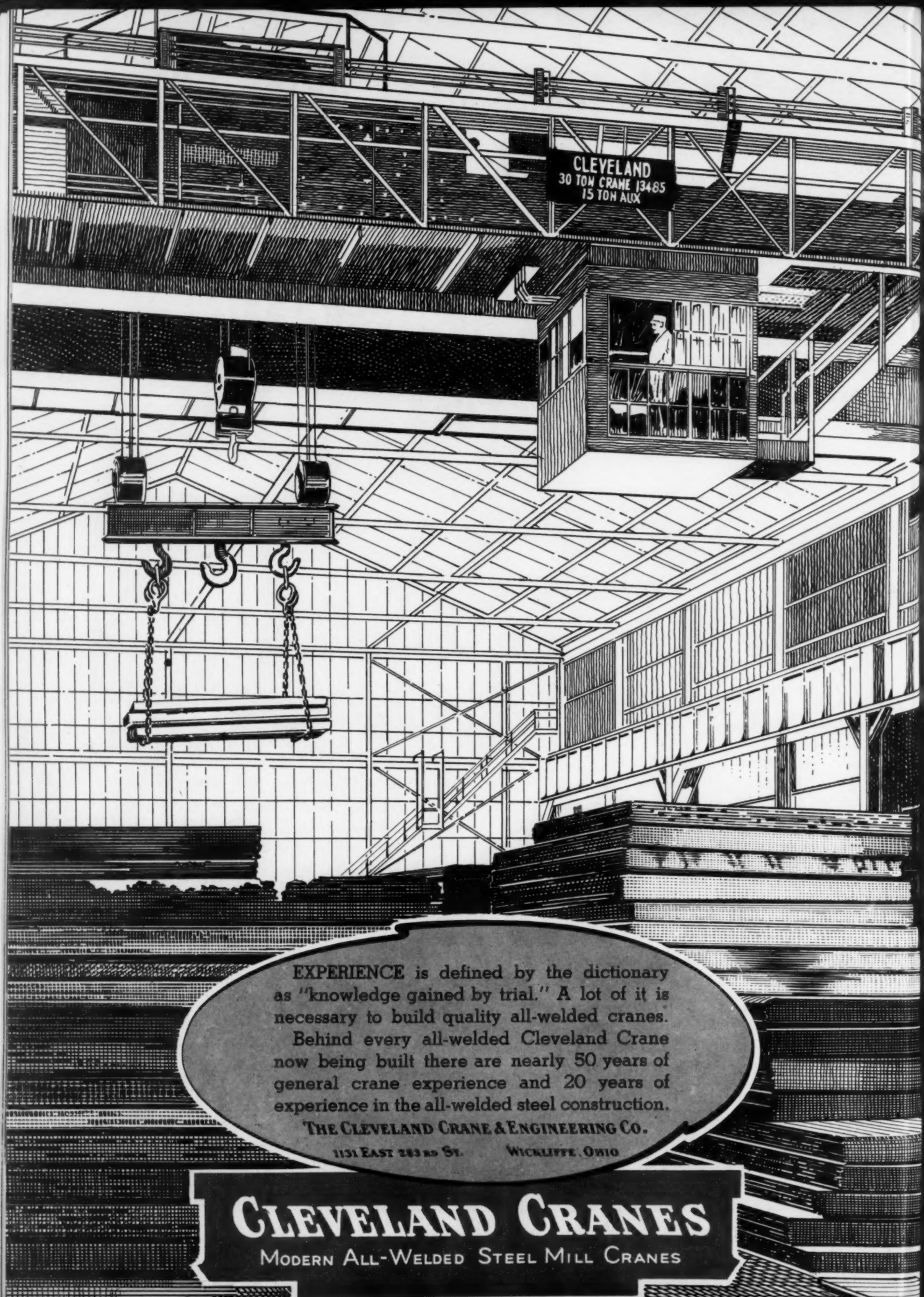
The truck in question was purchased in 1931. The original investment has long since been written off—paid for in a short time by actual savings in handling costs and more efficient use of warehouse space. The owner has enjoyed 14 years of trouble-free service—possible only with electric trucks, which also mean quiet, smooth operation, lowest power costs and maximum safety.

Your Baker representative can show you how these advantages of electric-powered industrial trucks will apply to your handling problems. If you don't already know him, write us direct.

EITA

Member:
Electric Industrial Truck Association

BAKER INDUSTRIAL TRUCK DIVISION
of the Baker-Raulang Company
2166 WEST 25th STREET • • CLEVELAND, OHIO
In Canada: Railway and Power Engineering Corporation, Ltd.



EXPERIENCE is defined by the dictionary as "knowledge gained by trial." A lot of it is necessary to build quality all-welded cranes.

Behind every all-welded Cleveland Crane now being built there are nearly 50 years of general crane experience and 20 years of experience in the all-welded steel construction.

THE CLEVELAND CRANE & ENGINEERING CO.

1131 EAST 283rd ST. WICKLIFFE, OHIO

CLEVELAND CRANES

MODERN ALL-WELDED STEEL MILL CRANES

Crops *and* Shorts

STEEL payrolls in 1945 totaled $1,645,000,000, twice the 1936 figure although 1945 production was only 49 per cent above the 1936 figure. The total was divided between 551,200 employees who averaged 39 hours per week and $1.22 per hour.

▲

JUST in case you know someone who wants to go to Germany, the Commerce and War Departments are looking for technicians to search the files of German industry for information of value to American industry. They will also welcome suggestions as to specific information that should be sought, and will arrange special missions for groups interested in specific German industrial methods of general value to industry. Suggestions should be made to the Office of the Publication Board, Department of Commerce, Washington 25, D. C.

▲

POSTED on the wall in a telephone booth in Pittsburgh's Federal Building: "When America was discovered, Indians were running the country with no taxes, no indebtedness, no relief, and the women did all the work. White men thought they could improve on a system like that."

▲

ADD to GI gripes: "God and the soldier we adore in time of danger, not before. The danger passed and all things righted, God is forgotten and the soldier slighted." This was written in 1696 by Britain's famous General Marlborough.

▲

THE successful use of oxygen instead of air in a small pilot plant in Russia is to be followed by application of the process to a large blast furnace. It is thought that the new blast method can ultimately lead to a continuous process of steel making.

▲

THE Safety Bulletin of Continental Foundry and Machine Company says: "Quality, that priceless ingredient, silently broadcasts to the world the excellence of the product. It attains for those who make the product a popularity that outrides all competition." Now, if we could just apply that silent broadcasting to those commercial announcements on the radio . . .

ACCORDING to the American Iron and Steel Institute, production loss during the steel strike amounted to about 7,500,000 tons of ingots, equivalent to 5,250,000 tons of finished steel — well over one month's shipments. If we add to this the loss which will stem from the coal strike, we can harbor no doubts as to the progress of our reconversion.

▲

WITH the recent death of a daughter of a man who fought in the battle of New Orleans, the United States has reached the end of its payments for the war of 1812. On this basis we should clean up World War II by the year 2080, but perhaps it's overly optimistic to think we'll have the war debt cleaned up by that time.

▲

IT has been estimated that the 113 day General Motors strike cost the workers $140,000,000 in wages. With the 18½c per hour increase instead of General Motors' pre-strike offer of 11c per hour, it will take the strikers five years to make up their lost income.

▲

FROM a recent letter in Time: "It is a gloomy moment in history. Not for many years — not in the lifetime of most men who read this paper — has there been so much grave and deep apprehension; never has the future seemed so incalculable as at this time.

"In France the political caldron seethes and bubbles with uncertainty; Russia hangs as usual, like a cloud, dark and silent upon the horizon of Europe; while all the energies, resources and influences of the British Empire are sorely tried, and are yet to be tried more sorely, in coping with the vast and deadly Indian insurrection, and with its disturbed relations in China. It is a solemn moment, and no man can feel an indifference — which, happily, no man pretends to feel — in the issue of events.

"Of our own troubles (in the U. S.) no man can see the end."

The above, though it sounds current, is from Harper's Weekly, Oct. 10, 1857 . . . 88 years ago!

▲

IT is reported that Japanese steelworks have recently produced 19,000 tons of steel and will in the next two months produce more tonnage to meet current civilian needs. Total production will eventually be at the rate of 2,000,000 tons per year. Steel is at present being made principally from scrap, including war materials.

▲

WITH the gradual return of men from the military forces, the staff of the Iron and Steel Engineer and of the Association is returning to a more normal footing, and will be able to give improved service to readers and members. As previously mentioned in this magazine, I. E. Madsen, a former lieutenant-colonel in the Army engineers, joined the staff last fall, and on January 1, J. D. Kelly came back from the Navy. In February J. R. "Bud" Scott, the man with the camera and the big cigar, gave up his career in the Air Forces and returned from the Pacific theater to the prosaics of civilian life. Finally, on April 1, A. W. Erickson, Jr., who had been a major in the ordnance department, came back from the Mediterranean theater to bring our staff up to prewar basis.

No sag...no drag...Coils ride safely and gently on LINK-BELT Conveyors

Coils that ride the Link-Belt Conveyor make their trip safely. Ample bearing surfaces and sturdy construction prevent the sag and drag that scuff strip edges. Telescoping is eliminated and the reduction in edge damage has a marked effect on scrap losses; accomplishing a reduction in the cost of tin plate production.

Link-Belt conveyors offer carefree operation. Ruggedly built, smooth running, Link-Belt offers designs for handling coils in various positions, allowing complete flexibility in mechanical handling.

Discuss your plans for mill modernization with a Link-Belt Engineer, the man backed by broad experience in your materials handling problems.

SERVICE TO STEEL BY LINK-BELT . .

Complete line of Chains for transfer tables, coil conveyors, furnace conveyors, feeder and catcher tables, sheet pilers, draw bench and other equipment . . . Elevators and Conveyors of all types, such as belt, bucket, screw, flight, Bulk-Flo, drag chain, apron, Sidekar-Karrier, trolley, Oscillating-Trough, etc. . . . Vibrating Screens . . . Dryers and Coolers . . . Skip Hoists . . . Car Dumpers . . . Car Spotters and Haulage Systems . . . Portable Conveyors and Bucket Loaders . . . Traveling Water-Intake Screens . . . Automatic Stokers . . . Silent and Roller Chain Drives . . . Speed Reducers and Increasers . . . Variable Speed Transmissions . . . Sprockets . . . Gears . . . Clutches . . . Couplings . . . Babbitted, Ball and Roller Bearings, etc.

10,281

LINK-BELT COMPANY

Chicago 9, Pittsburgh 19, Cleveland 13, Detroit 4, Indianapolis 6, St. Louis 1, Kansas City 6, Mo., Philadelphia 40, Atlanta, Dallas 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8. Offices in Principal Cities.

DEADENDING

Heavy Feeder Cables

HERE'S a Keystone "hard-to-beat" combination for deadending heavy cables. Long clamping surface provides positive grip on conductor. Note clamp is round and of small diameter to facilitate taping and is free of sharp projections which might pierce tape insulation. In combination with the Keystone Giant Strain Insulator which is porcelain covered for all weather service and backed by over 30 years of unfailing service you have a "hard-to-beat" combination. You can do a better, longer-lasting job with Keystone.

Ask for Catalog

ELECTRIC SERVICE MANUFACTURING CO.

Former Name—Electric Service Supplies Co.

17th & CAMBRIA STREETS • PHILADELPHIA 32 • PA. • Branches in Principal Cities

WEAN

Sheet Shearing

THE WEAN ENGINEERING CO., INC
WARREN, OHIO

WEAN EQUIPMENT FOR CONVERSION OF STRIP IN COIL FORM TO FLAT STEEL SHEETS IN ACCURATE LENGTHS

Subsidiary Company
THE BRODEN CONSTRUCTION CO.,
Cleveland, Ohio

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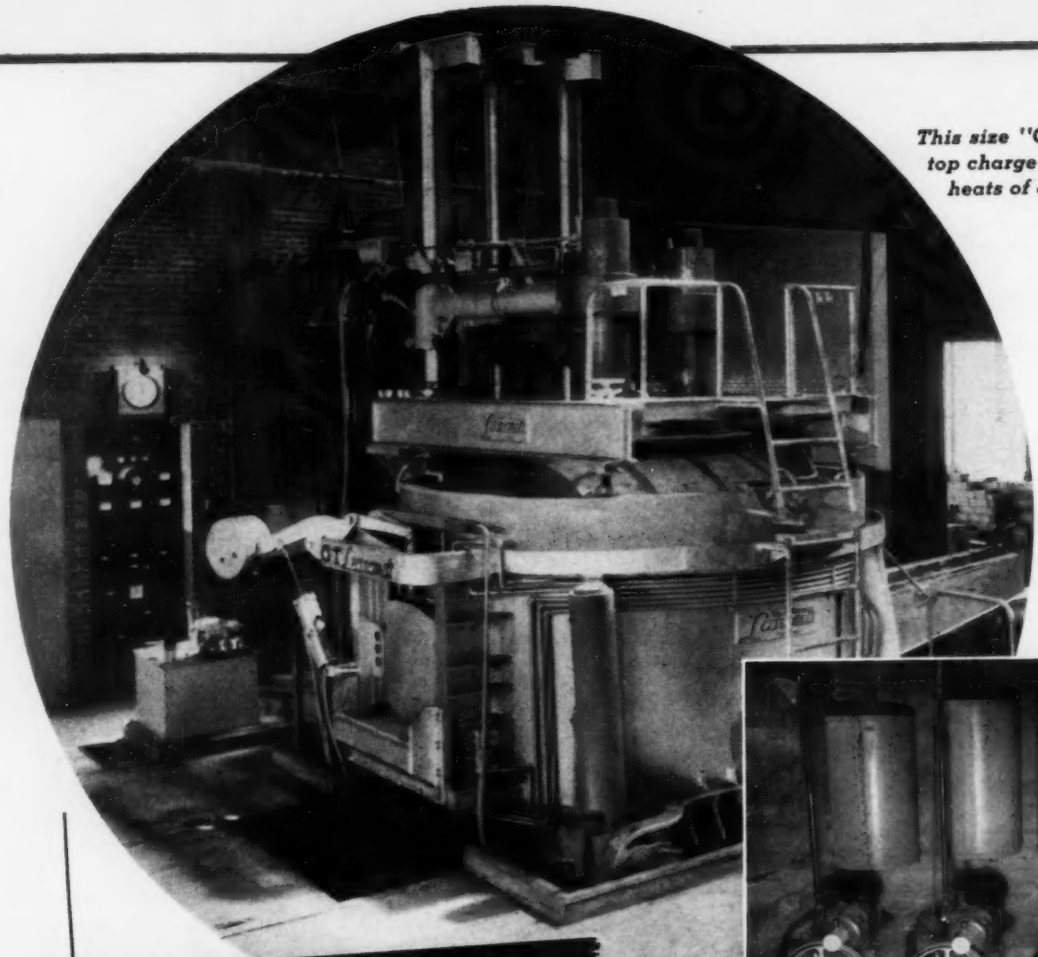

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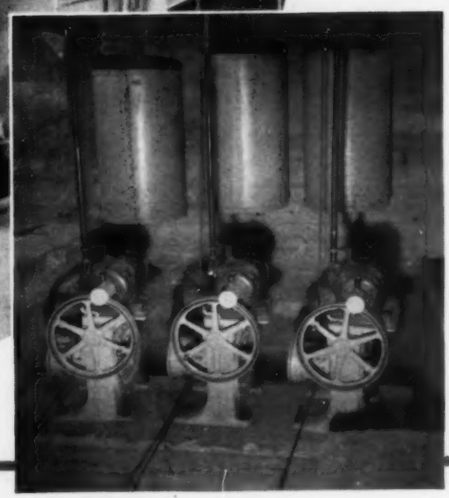

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THE SENDZIMIR *Precision Cold Strip Mill*

. . . . it has long been recognized that rolling with small diameter rolls has many advantages, particularly if the main objection of roll deflection could be overcome . . . . the Sendzimir mill offers one solution to this problem . . . .

by T. Sendzimir, VICE PRESIDENT

ARMZEN COMPANY

MIDDLETOWN, OHIO

▲ THE unique design of the Sendzimir cold strip mill makes it possible to effectively use work rolls of considerably smaller diameter, for a given width, than any other design. Work rolls are definitely too large when they flatten at their contact area with the strip to such extent as to materially diminish the reducing power of the mill. Since the flattening depends on the roll separating force, a certain diameter of roll may be acceptable for some softer metal and at the same time, may be definitely too large for a harder metal.

To briefly review the characteristics of small work rolls and their effect on the rolling process, small work rolls considerably reduce the pressure area between the rolls and the strip and, at the same time, they increase the bite angle. This means that the total pressure that the mill has to take is considerably smaller than with mills using large diameter work rolls, so that the mill itself and its bearings can be much lighter. The bite angle being larger, for any given pass, the nature of the frictional contact, as between the rolls and the strip is also changed. On mills using large diameter work rolls, the latter are practically geared to the strip, by friction. Back of the non-slip point, the strip is slipping back in the long pressure area and back tension is somewhat helpful here but friction is so high that it tends to reduce that helpful effect, especially beyond the center of the roll bite. On the contrary, with small work rolls, the average angle of the roll bite is more open and therefore tension is much more effective in further reducing the roll separating force. Furthermore, the roll bite being relatively short, the length over which slippage occurs is much shorter, thereby reducing the amount of heat generated by friction, and also reducing the wear on the rolls. It is surprising how long these small diameter rolls last, even when taking heavy passes.

Figure 1 compares the actual proportions of the strip in the roll bite for small and large diameter rolls. With other conditions equal, a 0.030 in. strip is cold reduced to 0.018 in. in both cases, resulting in a 40 per cent reduction. Assuming a 1000 fpm delivery speed of the strip, with 40 per cent reduction, the feeding speed is 600 fpm. Therefore, since the surface velocity of the work rolls is about the same as the delivery speed or 1000 fpm, the strip slippage at entrance into roll bite is the difference of the two, namely 400 fpm in both cases. In the roll bite where this slippage occurs, the pressure on the strip is high, 100,000 to 300,000 psi and even higher, which means abrasion or wear of rolls and power consumed, on the top of energy consumption required for the plastic elongation of the strip. The fact that such slippage occurs over a much lesser area, in the case of the small work rolls means longer roll life between grinds and savings in power consumption.

The strip is, of course, subject to tension, back tension on the feeding side and front tension on the delivery side of the roll bite. It will be clear from the figures that

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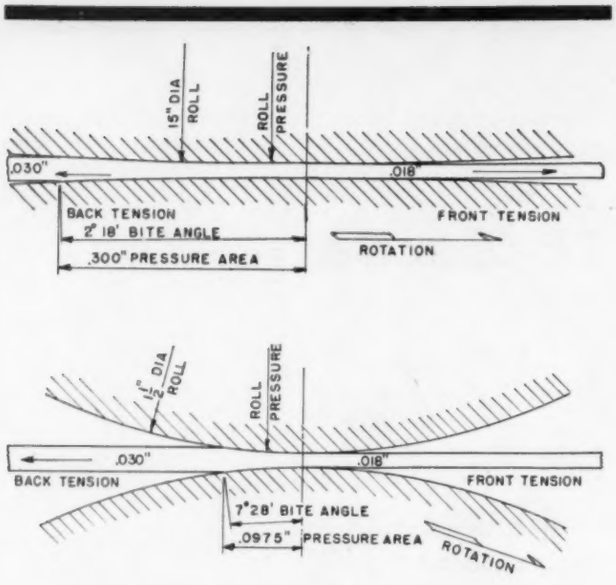


Figure 1 — Comparison of actual proportions of strips in the roll bite. Cross section shows the top figure with 15 in. diam work rolls and the bottom figure with 1½ in. diam work rolls.

it is the back tension that is mainly effective in reducing the roll pressure, roll separating force, that is necessary to obtain a given reduction. With adequate tension, the roll pressure can be reduced by 30 to 40 per cent and even more for the same reduction.

On the other hand, friction between the rolls and strip tends to diminish the beneficial effect of such tension and here again the large diameter work rolls are at a disadvantage. In the long and nearly parallel roll bite in the top figure, the effect of tension is largely limited to the immediate vicinity of the entry of the strip into the bite of the rolls and is lost progressively, as the strip moves further into the roll bite. The short and relatively open roll bite of the small rolls shown in the bottom figure, permits the tension to exert its influence quite effectively over the full pressure area.

The relative lightness of frictional contact between the strip and the small work rolls has also another marked effect on the rolling of strip, and that is, that tension in the strip, especially the front tension, is much more effective in producing a flat strip, since any deviation from flatness immediately translates itself into minor differences in tension, across the strip, and these automatically are compensated for by little adjustments through slippage within the bite of the rolls, making it relatively easy to produce a flat strip even in very light gauges.

Freedom from camber is another result of this condition, and finally, there is still one important practical effect due to the use of small rolls, one that will be clear on the strength of the above considerations and that is, the improvement in the edge of the strip. With large diameter rolls, friction within the roll bite which retards the back-flow of material and detracts from the effect of back tension, finally results in a greater specific pressure at the non-slip point and consequently, a considerable degree of extrusion, ahead of non-slip point. These conditions are upset in the zone close to the edge of the strip where that pressure is relieved because the strip is more free to spread sideways. The result is that the stress conditions within the roll bite that produce the flow of metal no longer exist at the edge zone. In the roll bite, plastic deformation finally is produced by shearing stresses, while at the edge zone, tension gradually comes into prominence and this causes the edge of the strip to crack. Some metals are particularly susceptible to this trouble and cracks as deep as ½ or even 1 in. from the edge are common, although the original strip was sound.

With small rolls, conditions at the edge do not vary greatly from the rest of the roll bite. The width of the edge zone is, in most cases, only twice or three times the thickness of the strip and even metals that are quite touchy in this respect, can be rolled with smooth edges that do not require trimming.

MILLS WITH BACKING ROLLS

The above discussion concerns rolling characteristics of small versus large diameter rolls only. It has nothing to do with the mill design. A miniature 2-high mill, say with 1 in. diameter by 1 in. long rolls, needs no backing rolls whatsoever, and yet all the above discussed features will apply to it and all the advantages of small rolls will be realized. When one starts to roll wide strips with slender or small diameter rolls, the question of roll backing arises, and it is an important problem. However, backed rolls present no further advantages in the process of rolling. A simple 2-high unit is just as advantageous, within its width capacity, as the most elaborately backed Sendzimir unit, or other small roll diameter mill, provided the roll diameters are the same. The roll pressure per inch of width, the effect of front and back tension and the other characteristics apply equally in both cases.

Having shown that small diameter work rolls are desirable for reduction of metals and especially for cold reduction, particularly down to light gauges, let us consider next the problems confronting the designer of a mill embodying the use of such rolls, especially for wide strips. Roughly speaking, a roll will not be rigid enough unless the diameter is about the same as its working length, or only slightly less. But a long and slender work roll can be backed by another roll, contacting it along the generant that is opposed to the pressure area. Evidently the backing roll should be of the same length as the work roll it supports, but its diameter can be as big as the designer feels is enough for adequate rigidity. If both work rolls are backed by one backing roll, we have a four-high mill; if each work roll is backed by two rolls, we have a cluster mill. The latter arrangement imposes a further purely geometric limitation on the size of the work rolls which cannot be much less than 40 per cent of the diameter of the backing rolls. Therefore, with this roll arrangement, further backing rolls may be added outside of the first backing rolls so as to arrive at ultimate backing rolls of sufficient diameter. An example of such arrangement is the Rohn mill. These mills have one thing in common. They rely on a roll as a backing element. A roll is composed of the roll body proper which contacts the roll it backs along virtually its whole length, and a roll neck at

each end of a smaller diameter than the roll, to provide room for a bearing that must be of sufficient capacity to bear the enormous roll separating force. These bearings, of which there are two, one on the right and one on the left side of the rolls, are located in rigid and heavy mill housings. Each housing has a screwdown, or means for controlling the gap between the rolls and is, of course, subject to the roll separating force substantially throughout its length, which means that it stretches quite a bit when roll pressure is applied, even with very heavy designs. The backing rolls bend or deflect under the rolling pressure, like a loaded beam deflects, and this deflection is, of course, biggest at the spot corresponding to the center of the strip and diminishes progressively toward the edges of the strip. It is, therefore, necessary to provide the backing rolls with what is called a crown, that is make their diameter a little less toward the edges of the strip so as to compensate for this deflection.

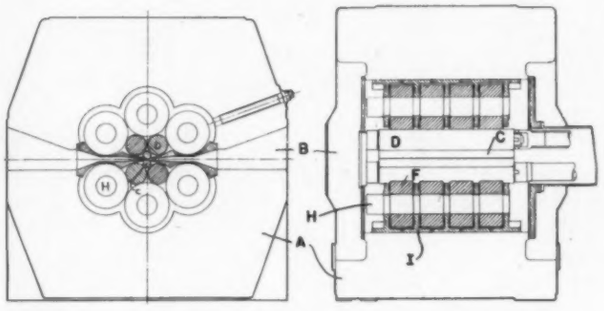
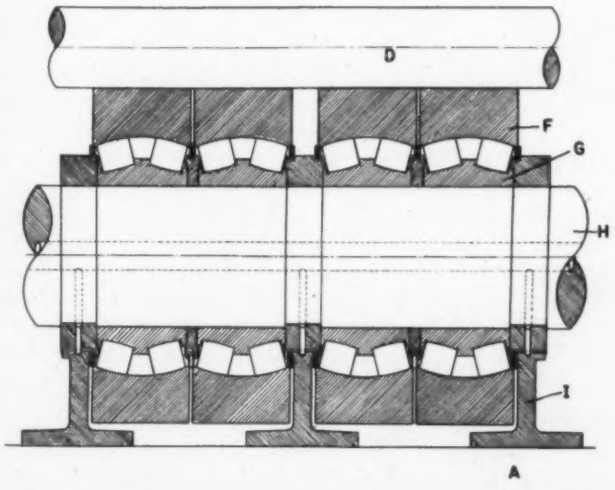


Figure 2 — On left is shown a cross section and on the right is shown a longitudinal section of a typical Sendzimir mill. The steel housing consists of beams A and columns B. Work rolls C are driven by intermediate rolls D. Pressure exerted by the work rolls in the roll bite is transmitted, inch by inch, into the intermediate rolls D, which do not have enough rigidity to withstand deflection but transmit the pressure to the casters F.

Figure 3 — Casters F are outer races of roller bearings of sufficiently heavy section to withstand localized pressure by rolls. The inner races G are mounted on a dead shaft H which is supported, at regular intervals, by saddles I mounted in the bore of the beam A (see Figure 2) of the mill housing. By turning shaft H, which is eccentric, casters F can be raised or lowered, which in turn changes the position of the intermediate rolls and, therefore, the work rolls (screwdown).



BACKING PRINCIPLE OF THE SENDZIMIR MILL

The Sendzimir cold strip mill falls into a different class in that it uses no backing rolls at all. An example may serve best to explain its backing principle. Many of us have seen a punch or drill press for making holes in steel plates in a boiler shop. These plates must be free to move horizontally, to be correctly positioned in the press, but they would bend under their own gravity unless uniformly supported. A caster bed is provided for this purpose consisting of a plurality of evenly spaced pillars each with a caster on the top. The pillars are firmly bolted to the foundation plate and the casters are all of the same height. When a steel plate is placed on top of these casters, it is supported at a plurality of spots that are all situated on the same plane that can be considered as rigid, and the deflection of the plate due to gravity is limited to the sag between the individual casters which can be placed as close to each other as necessary in order to make that deflection negligible for practical purposes. At the same time, the plate can be moved horizontally at will, because the casters turn freely offering very little resistance to such movement.

The roll pressure in a cold strip mill is much higher than the weight of a plate in a boiler shop, but the principle is still the same. The rigid foundation in our type mill is a solid steel beam and not a concrete plate and this beam is the only element that is rigid enough to prevent deflection of the work rolls by the roll separating force and, for obvious reasons, it can be made much more rigid than a backing roll in a conventional mill.

The Sendzimir cold strip mill, shown in Figure 2, usually consists of one solid steel housing comprising an upper and a lower beam which gives support to spaced casters and these beams are connected by solid vertical columns. Since the object of the casters is to support a roll along one generant, they are all mounted on one shaft, there being stationary supports on the shaft, one between each two casters, in order to rigidly support this shaft at spaced intervals. These supports or saddles are of course, fastened directly onto the beam of the housing. Details of the casters are shown in Figure 3.

Depending upon conditions of rolling, our mill may have two, three, four or more caster shafts per work roll and may use one or more sets of intermediate rolls, between the casters and the work rolls. But these intermediate rolls, though larger in diameter than the work rolls, are not backing rolls in any sense. They simply transmit the roll pressure inch by inch from the work rolls onto the casters, always in a plane perpendicular to the work rolls and they would function just as well had they been composed of small discs, like poker chips.

With the caster backing principle, the Sendzimir mill can use small work rolls even for relatively wide strips;

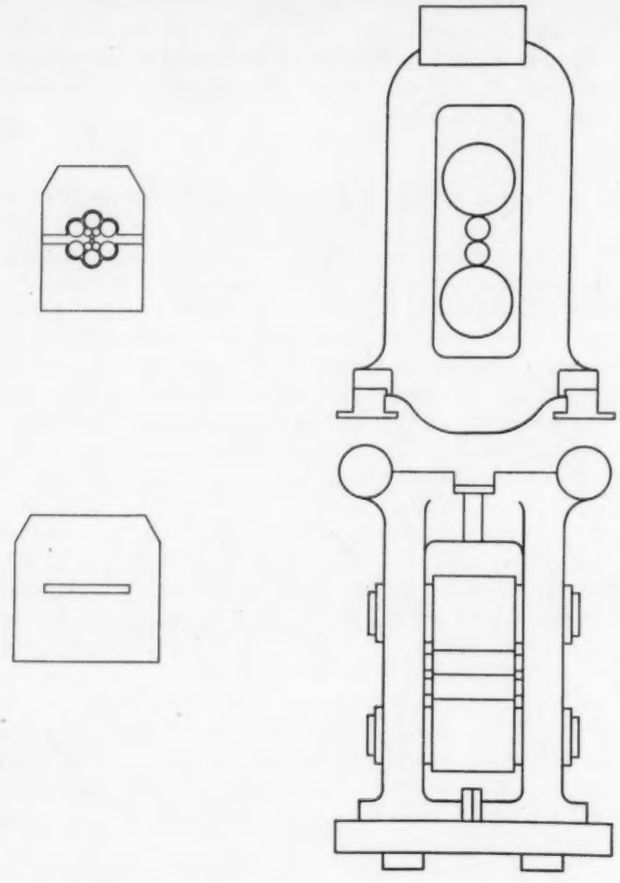


Figure 4 — General proportions of a Sendzimir mill, weighing 60 tons, compared to a four-high mill, weighing 300 tons, for a 50 in. wide strip. The top figures are cross sections and the bottom figures are the front elevations.

in fact the roll diameter does not depend upon the width of the strip. Mills for a 50 in. wide strip using 2¼ in. diameter work rolls are in operation, and we have actually under construction, mills with 1½ in. work rolls which take a 40 in. wide strip. Even this is not the limit, and for rolling, for example, foil gauges of very hard materials, still smaller diameter rolls are provided.

RIGID MILL HOUSING

Since the rolls are small, the caster diameter is also relatively small, so that the whole housing of the mill is rather small and compact. The distance between the roll bite where the roll separating force is generated to the nearest spot in the beam of the housing where it is finally taken up, is hardly ever more than 20 in. which is little compared to the tall housing of a 4-high mill as shown in Figure 4. Consequently, the housing of a Sendzimir mill can be made much more rigid than conventional mills. The total deflection is usually of the order of 0.0003 to 0.0007 in. and, after subtracting the stretch in the columns, the center of the mill deflects a mere 0.0001 to 0.0002 in. more in the center than toward the edges of the strip. This is little but, with a small roll diameter, even this is noticeable, especially when light and heavy passes are taken alternately.

But here, the caster backing principle offers a means of compensating even for this small difference in deflection by introducing into the backing system another elastic element with inverse deflection characteristics, having the highest deflection opposite the center of the strip and the smallest deflection opposite the edges of the strip.

PRINCIPLE OF COMPENSATED DEFLECTION

Compensated deflection is an important feature and it will probably be better to explain the underlying principle on a schematic model shown in Figure 5. This consists of one flat bar of spring steel supported at its ends. If we load this bar uniformly between these two supports at so many ounces per inch with a chain or a roll of washers, the bar will deflect and the deflection will be biggest in the center of the bar, Figure 5-B. If we double the load on the bar, by using another chain twice as heavy as the first one, the bar will deflect in a similar way, but the deflection will be twice as big excluding the deflection produced by the bar's own weight as seen in Figure 5-C.

The other part of our model is a series of steel wire springs, each made of several turns of steel wire, Figure 5-A. They all have the same diameter but the number of turns vary so that their elasticity is not equal. If we hang up a spring on some support and attach a load to it at its lowest point, it will deflect, but the shorter springs will deflect less than the weaker ones. In this particular case, these wire springs have been calibrated to compensate for the deflection of our flat steel bar. These springs are suspended from the bar in such order that the strongest are near the center and the weakest near the ends and they are spaced evenly over the length of the bar. We place the bar upon its end supports and now, instead of putting our load on top of the bar, we hang our load onto the springs, see Figure 5-D. In this way, each spring carries its proportion of the weight of the load and, through the springs, the weight of the load is further transmitted onto the bar. The bar, therefore, deflects as before, neglecting deflection produced by its own weight and the weight of the wire springs, the deflection at the center being the greatest, while the springs deflect in exactly the opposite way. We have placed the strongest springs at the center where the bar deflects most. These springs will deflect least. Our longer springs are placed progressively toward the ends and these will of course deflect correspondingly more. If our springs have been properly calibrated, the load will be a straight line, because each part of it is subject to the sum of the two deflections: the deflection of the bar at the spot and of the corresponding spring and, with proper calibration, the sum of the two is uniform, over the whole length of the bar.

But, since these deflections are all elastic, if the elastic deflection of the springs has been properly calibrated for one load, it will be just as perfectly compensated for at any other load within the elastic limit of the elements, that is, the bar and the springs. If we use a load twice

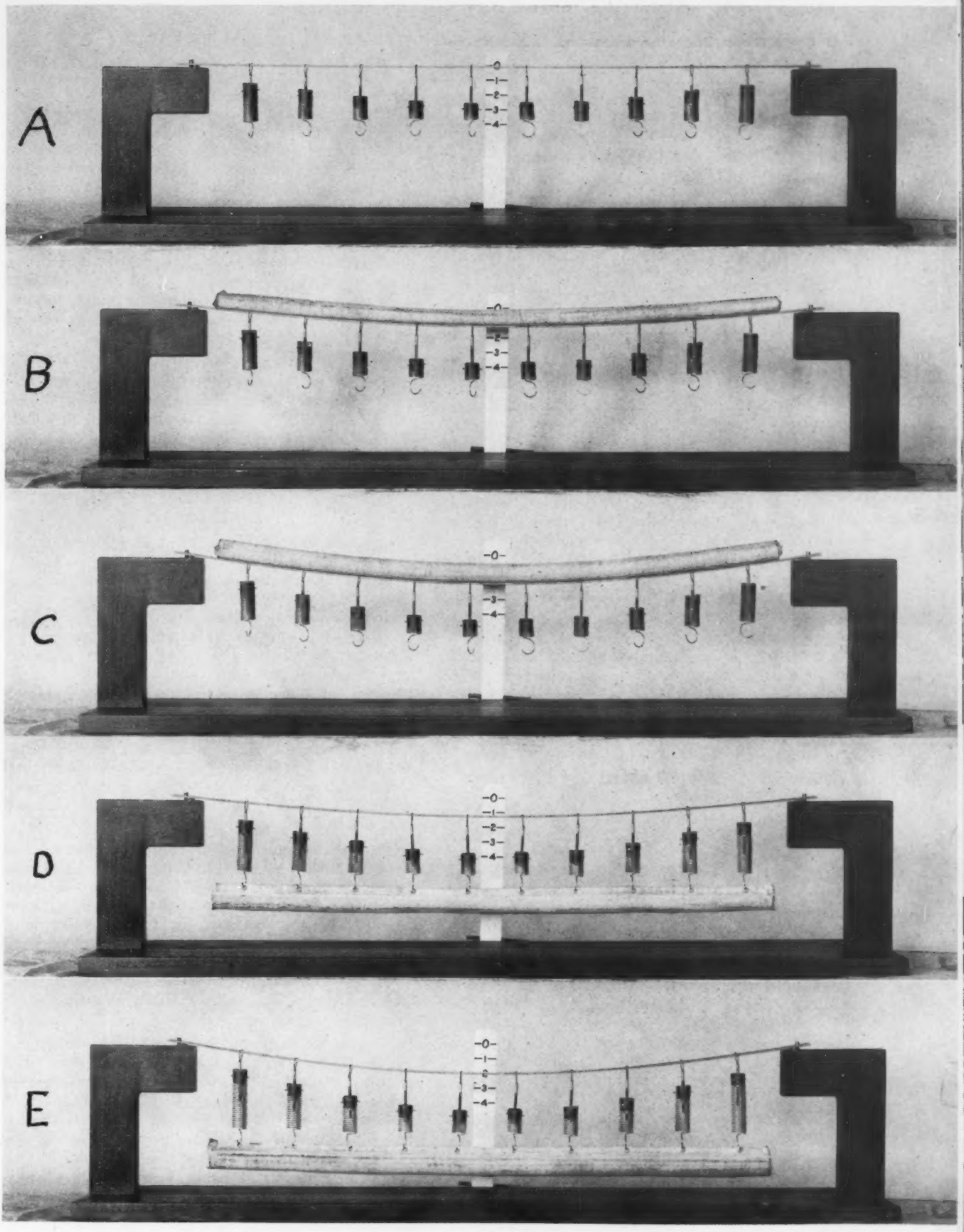


Figure 5 — Model to illustrate principle of compensated deflection.

as heavy as the first one, the deflections will be double in amplitude, but the load will still be a straight line, as shown in Figure 5-E.

The compensating action will also be there if we do not load the whole length of the bar, but only a portion of it, such as placing a load half the length of the former load, symmetrically, near the center of the bar.

This apparatus only demonstrates the principle of compensating for a deflection of known characteristics, by artificially superposing another deflection of inverse characteristics. There are several methods of applying this principle to the mill and the simplest is to control the side deflection of the out-lying caster shafts. This side deflection is inevitable and, as far as roll deflection is concerned, it is superimposed on the main deflection. For the purpose of control, slots are provided in the housing to render independent that portion of the beam which is subject to the side deflection. The portions situated near the ends of the beam are then progressively reduced in thickness, so as to increase their sideways deflections progressively toward the ends of the beams where its main deflection is smallest.

A mill that is thus compensated for deflection gains of course in accuracy, but the main advantage in practice lies in the fact that heavy passes can be alternated with light ones without effect on flatness or rolling characteristics of the mill. A heavy reduction pass can be followed by a very light sizing pass and the strip is in no danger of being thrown out of shape as is the case with all mills where roll deflection is controlled by backing rolls.

Compensation for deflection is not possible on mills using backing rolls because, irrespective of the plane of support whether with a 4-high or cluster backing, there is only one compensating deflection which can be established by increasing the size of the roll toward the center of the strip.

CASTER RELIEF

This does not mean, however, that all rolls and casters on a Sendzimir mill are strictly cylindrical. Under rolling pressure, both the casters and the rolls flatten somewhat at their line of contact. But, as far as the caster is concerned, there can be no pressure transmitted beyond its physical limits, or its edges, whereas the roll is a continuous cylindrical body and the local impression or flattening cannot abruptly disappear at the line facing the edge of the caster, but will disappear gradually corresponding to a natural flow line. Therefore, the pressure is not uniform over the length of the contact area but, if the casters are not relieved, it is considerably higher at the edges of the casters than over the rest of their faces and this results in cutting or marking the roll face. To prevent this, the casters are usually tapered somewhat at the edges.

A good way to ascertain if a relief is adequate, is by inserting a strip of metal foil between the roll and the caster and then applying full pressure with the screw-down mechanism. On removal, the foil will show the pressure area as a surface impression of uniform width except for the last $\frac{3}{16}$ or $\frac{1}{8}$ in. from each edge. Casters which are so relieved will leave no traces on the rolls they back.

ROLL RELIEFS

A milder but somewhat similar situation also exists between the work rolls and the intermediate rolls at the two edges of the strip where the roll pressure also falls off abruptly. Throughout the width of the strip the two intermediate rolls which back the work roll show a flattening, the same as between the intermediate rolls and their casters. But that flattening also will not disappear suddenly at the edge of the strip, but will continue beyond this edge, owing to the relative rigidity of the roll for $\frac{1}{2}$ in. or more. Were it possible to use work rolls exactly as long as the width of the strip, there would be no problem involved, but there is no such thing as strip of exactly uniform width. In addition, the strip may also shift sideways $\frac{1}{16}$ in. or even more during the rolling.

The result is again a necessity for relief, and it is preferable to relieve the intermediate rolls because they are ground only rarely and therefore it does not cost much to spend the time necessary to provide the reliefs. Without edge reliefs, the intermediate rolls would have a tendency to bend the work rolls slightly toward the strip and thus produce edge waves.

BASIC REASONS WHY MILL IS ACCURATE

Perhaps the most striking characteristic of the Sendzimir mill is the fact that the small work rolls and all their backing elements are packed within a relatively small cavity in a rigid steel housing. The housing itself represents essentially a heavy ring structure, with slots provided for the passage of the strip. The cavity or the inside of this ring consists of accurate cylindrical bores for the spaced supports of the individual caster shafts and these are, of course, machined accurately. Individual bores are parallel to within 0.00015 in. and tested by using gauge blocks. What is still more important, this accuracy can be achieved also in relatively large housings for rolling wide strips because these inside surfaces are finally scraped in by hand.

This means that the foundation for ultimate mill accuracy is there. From there on, everything that goes into the mill consists of small heat-treated steel parts that are ground to accuracy limits much finer than is possible with large backing rolls of conventional mills. Moreover, the spaced supports are individually ground to close limits and, therefore, there is no cumulative error that would increase with the width of the mill. This insures a strict parallelism of all rolls.

Furthermore, all these elements which are powerful backing means but which carry relatively small pressures compared with large-roll mills, represent small masses and small sections of metal. These parts are all surrounded by a circulating bath of lubricant that carries away all the heat as soon as it is generated. Lubricant is uniformly delivered under pressure to each of the spaced backing casters and escapes into the general oil bath comprised within the mill cavity where it maintains the work rolls and the intermediate rolls at uniform temperature. It is then passed through the filters and the cooling tank and recirculated. Of course, with the small rolls and, therefore, with relatively little

pressure and heat generated within the mill, heat dissipation is rendered still easier, which means that heavy reductions at high rolling speeds are obtainable.

CROWN ADJUSTMENT

It has been shown how the design of this mill makes it possible to insure parallelism of the work rolls under all load conditions within high limits of accuracy.

In practice, however, the operator often needs to depart from such strictly parallel roll profiles and here, the mill provides a convenient means of adjusting the roll profile without the necessity of regrinding the rolls to another shape. This is effected by providing adjustable height saddles, usually on only one of the shafts. The saddles of this shaft, instead of having their bores concentric, are provided with eccentric bores. These eccentric saddles are provided with a mechanism with whose aid they can be individually released and rotated through a certain angle, usually not over 3 or 4 degrees, and fastened again in the new position.

The effect is that the height of support at this particular spot is raised or lowered as the case may be, and consequently, more or less pressure is put on the two casters adjacent that particular saddle. Since the whole width of the strip is subdivided into a plurality of spaces between such supports, and since the rolls including all the intermediate rolls are elastic, any crown effect can be quickly and easily obtained.

If for instance, a strip should have slight waves on one side, this can be corrected by reducing somewhat the pressure exerted by casters facing that part of the strip and this in turn is done by rotating the individual saddles, each in proportion to the change the operator is desirous of producing, and locking them in their new positions. If he finds that he has over-done the adjustment, he can easily go back as much as he wants. The whole adjustment only takes a minute or so and no rolls or parts need to be changed.

FIELDS OF APPLICATION

Analyzing the broad features of the Sendzimir cold strip mill, one can determine to which fields of application it is particularly adapted, and some of these are as follows:

1. For reduction of wide strips of relatively hard metals and alloys down to light gauges. So far as is known, alloys like stainless steel or monel metal cannot be economically produced in strips, 0.0005 in. by 24 in. or wider, by cold reduction, even with intermediate anneals, but they can easily be so reduced on a suitable Sendzimir mill.
2. For very wide strips, such as 60 to 100 in. wide, of any analysis, from low carbon to the highest tensile alloy steels, reduced to any gauge including the lightest, where, in addition to other benefits, the first cost of the mill is low on account of its relatively light weight.
3. Whenever a very accurate strip is required, this mill produces strips within a gauge tolerance of from 0.0001 to 0.0003 in., depending upon the gauge and the metal. The strip can be made entirely parallel, without any heavy center at all, and with the edge tapers less than $\frac{3}{16}$ in. wide. For shim stock, deep-drawing sheets and many other applications, this gauge accuracy may be of value. In addition, the strip is free from camber and narrow width strips can be economically produced by slitting a wide strip into a number of narrow strips which will all be exactly the same gauge. In addition, they will run straight on the winders, since there is no tendency to produce camber after slitting.
4. The mill possesses certain advantages also in the high production type of work, as a reversing mill for tinplate strips. Not only can passes be saved, but the schedule is different. With large rolls, reductions are heavy during the first few passes, whereas the last passes are light. With the Sendzimir mill, the heaviest reductions are the last ones, and since the footage of the strip is the longest at light gauges, such distribution of passes saves valuable minutes on each coil, because it saves time on the longest passes. Moreover, the power demand of such mill is rather uniform, from the first to the last pass, whereas with large roll mills, the last pass usually demands very little power. This means that not only the mill itself, but the electric equipment also is less costly.

   High mill speeds coupled with heavy reductions can be used to great advantage, since heat dissipation is no problem with this mill.
5. These considerations apply even more strongly when the raw material for such stock as tin plates is heavy. On some Sendzimir mills in Europe where hot-rolled strips 40 or 50 in. wide are not available, long sheets are produced on 3-high mills and are pickled, squared and welded into strips. Such strips are usually $\frac{3}{16}$ in. thick and they are reduced easily to the regular tin plate gauges, the last pass being usually between 40 and 50 per cent.
6. Where very heavy single-pass reductions are desirable. On certain alloy steels and certain aluminum, copper and other alloys, single-pass reductions of the order of 75 to 85 per cent are produced and the resulting strip is smooth, flat and accurate. For instance, reduction of 0.020 to 0.003 in. in aluminum alloys, from 0.013 to 0.003 in. in alloy steel, from 0.006 to 0.002 in. in high-carbon steel have thus been produced.

DISCUSSION

PRESENTED BY

M. D. STONE, Manager Development Department, United Engineering and Foundry Company, Pittsburgh, Pennsylvania

R. S. BURNS, Associate Director, Research Laboratories, The American Rolling Mill Company, Middletown, Ohio

T. SENDZIMIR, Vice President, Armzen Company, Middletown, Ohio

M. D. Stone: The important thing, I think, is the pros and cons of a small work-roll in reducing metal.

That is the thing that Mr. Sendzimir has brought to everyone's attention so properly. In Europe, for years now they have had other small work roll mills. There is the Rohn mill, for instance, of which there is one in this country that has been working for several years.

I agree with Mr. Sendzimir pretty much, at least qualitatively, in the various points that he raised, but not entirely quantitively.

The small work roll has at least three definite advantages. One is that it does decrease the amount of pressure required to reduce strip. Roughly, as was shown for the 1½ in. roll, as compared to the 15 in. roll, the pressure is reduced by some 3 or 4 to 1. In some cases the ratio is even greater. As a result, it follows of course that a much smaller mill structure is required to supply the pressure. Another point in favor of the smaller roll is that it also results in less spreading. There is still spreading for a small work-roll, but it is less for the small roll than for the larger roll.

But there are also several disadvantages to a small work-roll, and many mills have been built and operated over a period of years with varied roll sizes, from which you can get a comparative picture of mills of work roll diameters of 15 in. or larger, with 6 in. or 5 in. or 4 in. The predominantly objectionable thing about the smaller work rolls is their rapid wear and the necessity for their frequent replacement if you wish to maintain good surface finish.

I have in mind several instances I might cite to illustrate this point. One mill that I know about has a 6½ in. diameter work roll, is doing a job of skin passing that is usually done on a 12 or 14 in. work roll mill. To maintain the desired surface finish of the strip, because of the fact it goes around so many more times due to its smaller periphery, and because the wear is a result of the surface fatigue, it is necessary to change work rolls from a minimum of five times to a maximum of eight times per eight hour shift, whereas on the 12 and 14 in. diameter roll mills, the changes are of the order of once a shift. Therefore, the economy of roll dressing tends to become the important consideration.

One can certainly make the large reductions, discussed, but the question is can one make them continuously, as a production routine, and at considerable speeds? In another case I have in mind, a fairly heavy schedule of four passes was taken, at the beginning of the operations, but the work roll wear, replacement and redressing was of such a magnitude that the operating company decided to ease the schedule and do it in 5 passes, next in 6, and finally in 7. With 7 passes, they decided that they had reached the economical number of passes for the schedule and size of work roll which they were using. So there is a point where economy or the anticipated economy is not realized. However, in those cases where economy is going to be a determining factor such as where one is dealing with very thin and very work hardening, hard rolling alloys, which involve intermediate anneals such as stainless and silicon steels, and some of the higher carbon steels, it is conceivable that there is a point where the smaller work roll will eliminate an anneal or two, not for metallurgical reasons but because the mill capacity has been reached, which will offset the additional cost of rolls, maintenance, etc.

There are, however, some other points I would mention about small work roll mills. For the heavier gauges, of the order of 0.030 in. and up, you will find you can take more reduction on the big than on the small work roll mill. Your limitation on the small work roll mill is the power or torque one can put into it, and that limits one; whereas, with a roll twice as big in diameter, you will be able to transmit almost 8 times the torque, so that one can take heavier reductions with large work rolls in the early passes than with small. And where one is not involved in going to extremely thin gauges, it will be more generally true throughout the entire rolling schedule.

Those are some of the general things. There are some other things of minor importance. I think Mr. Sendzimir mentioned, for instance, that the average 4-high mill will extend an eighth of an inch, if I remember correctly, whereas he is involved in only 3 or 4 thousandths in the frame type of mill such as he has described. It isn't as bad as that. You are not normally concerned with the strains in the housing. You will extend your housing roughly about a thousandth of an inch for every 20 to 30 inches of post length, and there will be some bending in the top of the yoke. So I would say that on the average, your total elongation will be the order of 0.010 to 0.020 in. Moreover, this factor is of no concern in a four-high mill, as far as roll contour is concerned, because both ends of the roll go up together and do not affect the shape of the rolls. And if one chose, one could put in heavier mills. However, we all could put in lighter mills than we do and have no qualms about it.

You also pay a penalty for the smaller rolls in the extra accuracy required, in extra grinding, etc., as was mentioned. It is true for both the work rolls and backing rolls that your general machining accuracies to start off with must be greater, and must be maintained. A smaller work roll mill is more sensitive. Where this tendency will lead is hard to predict, and can only be answered by trial. I feel certain, however, that if economy ever dictates a work roll size less than 1 in., or even 1½ in., that a construction like Mr. Sendzimir's or perhaps the Rohn mill, will be the answer.

R. S. Burns: I have no comment to make except that we would not expect, with our mill, which has 1¼ in. diameter work rolls, to start the reduction of a ¼ in. thick bar. In my opinion, the small work roll is not the universal answer to rolling mill procedure, and while I would not expect it to be entirely satisfactory in the reduction of heavier gauges, there is nothing like a small work roll when it is necessary to make heavy reductions on very thin material.

On the Sendzimir mill which is operating in our research laboratory, we believe the roll life is very satisfactory. Our rolls are 1¼ in. in diameter, made from tool steel, and average in the neighborhood of Rockwell C-65. It is not difficult to obtain this hardness on rolls of this diameter, and hence the abrasion resistance is somewhat better than ordinarily achieved on rolls of larger diameter. A feature which enters into the estimation of roll wear is the fact that on our mill we produce very little material over 0.005 in. thick, and hence roll wear can not be expressed in tons produced on a basis comparable with, say, 24 gauge.

T. Sendzimir: Mr. Stone has brought up certain

(*Please turn to page 66*)

Brent Wiley

IT IS WITH deep regret that we announce the death on March 19, 1946 of Brent Wiley, until recently the managing director of the Association of Iron and Steel Engineers, and editor of the IRON AND STEEL ENGINEER. Mr. Wiley retired on January 1, 1946, but continued to be an advisory consultant to the Association.

A graduate of Rose Polytechnic Institute in electrical engineering, Mr. Wiley first worked for Carnegie Steel Company at the Ohio and Homestead Works. In 1904 he went with Wellman-Seaver-Morgan Company as electrical engineer, and in 1906 he became associated with Westinghouse Electric and Manufacturing Company, where he spent the next 25 years. With this company he was closely allied with the developments of electrification in the steel industry.

Mr. Wiley, who succeeded John F. Kelly the first managing director of the Association, had a keen appreciation of the Association's work in the advancement of engineering in the steel industry. This enabled him to guide the Association in the pursuance of its aims. During the ten years of his directorship the Association made enormous strides and broadened the scope of its activities. During this period, the Detroit and Buffalo district sections were established, and the Rolling Mill Committee of the Association was formed. Mr. Wiley was deeply interested in establishing and revising standard specifications for various items of steel plant equipment, in furthering the educational work of the Association, and in increasing its service to the industry.

All who knew the quiet dignity and kindliness of Mr. Wiley respected him and mourn his passing.

WHAT'S LEFT OF

Industrial Germany?

. . . . the recent inspections made by American industrialists and engineers of German industry have in general exploded the myth that German engineering and science were superior to the American . . . .

by Roscoe H. Smith, SECRETARY
THE RELIANCE ELECTRIC & ENGINEERING COMPANY
CLEVELAND, OHIO

▲ TODAY, amid scenes of great destruction, life and business in Germany are being reorganized to a strange and uncertain future. Figuratively speaking at least, Germany is turned upside down and her industries are completely disorganized.

My recent trip took me through a section of Germany and nearby territory corresponding roughly to an area the equivalent of that which in the United States would be bounded by Buffalo, Pittsburgh, Cincinnati, St. Louis, Chicago, Detroit and Lake Erie.

To get there, I flew some 2800 to 3000 miles from New York to London, stopping at Shediac, New Brunswick; at Botwood, Newfoundland; and Foynes, in Ireland, on the River Shannon. Flying time was 21 hours 40 minutes, although total elapsed time, however, was two and one-half days because of engine trouble which fortunately developed before starting the long hop from Newfoundland to Ireland.

Civilian travel to England was possible even before V-J Day. As an investigator on a government assignment, I traveled, of course, as part of the Army; but on our plane were the board chairman and the chief engineer of a steel mill machinery company in Pittsburgh and three other civilians from Akron. Remember, this was V-J week. The Pittsburgh men were going at the request of their British associate company to confer on reconversion problems of the industry in England. The other men were headed for Sweden to re-establish that branch of one of Akron's rubber companies.

My assignment to the Technical Industrial Intelligence Branch of an activity sponsored by the Joint Chiefs of Staff resulted in my visiting some 25 German plants, including such companies as Brown Boveri, A.E.G., Siemens, Conz Electric, Hessenwerke, Obermoser Motoren Fabrik, Robert Boach, Krupp, Dunlop Rubber and Continental Rubber. In addition, I had the opportunity to visit the Morelli Company in Milan, Italy and the Als-Thom plant in southeastern France. These plants were operated under German direction during the war.

The general purpose of the trip, so far as I was concerned, was to look for anything new by way of design and manufacturing practices which would help us here in this country in the development of electric motors of industrial types.

Within Germany, traveling by jeep, by command car, and by weapon carrier, the assignments took me over a

Presented at the Cleveland, Pittsburgh and Birmingham District Session Meetings of the A. I. S. E., December 17, 1945, January 14, 1946, February 25, 1946, respectively.

crescent shaped area. Centering around Frankfurt, Wiesbaden and Mannheim in the Rhine and Main River district, I went north along the Rhine to Cologne and to Dusseldorf in the zone of British occupation, through the Ruhr district, spending some time around Essen, then northeast to the large rubber and tire manufacturing city of Hanover. From there I went north to Hamburg, then through the Russian zone to Berlin.

In the other direction from Frankfurt, the trip included such cities as Heidelberg on the Neckar River, Stuttgart and Ulm further south, and Munich to the east. Calls were made in the zone of French occupation in the vicinity of Freiburg, with a side trip over into southeastern France, to Belfort near Basle, Switzerland.

German industry without question has received a staggering blow. In its revival, it is struggling to operate sufficiently to support at least the civilian needs which the occupation military governments are trying to meet. Just as many German cities are largely rubble today, many of the German electric motor manufacturing plants are severely damaged. In some plants, temporary repairs to buildings have made it possible to resume operations with limited output, perhaps 20 to 25 per cent of normal. Machine tools on the other hand have come through the bombings surprisingly well. In fact, unless hit directly, machinery in general does not appear to have been harmed beyond reasonably easy repair.

Labor is ample. Many operations have for years been done by women and they are not only available but anxious to be working. Why? Well, one reason certainly is because food rations are graded by useful occupation as well as by personal need. It is, therefore, somewhat a case of "Work, or you don't eat."

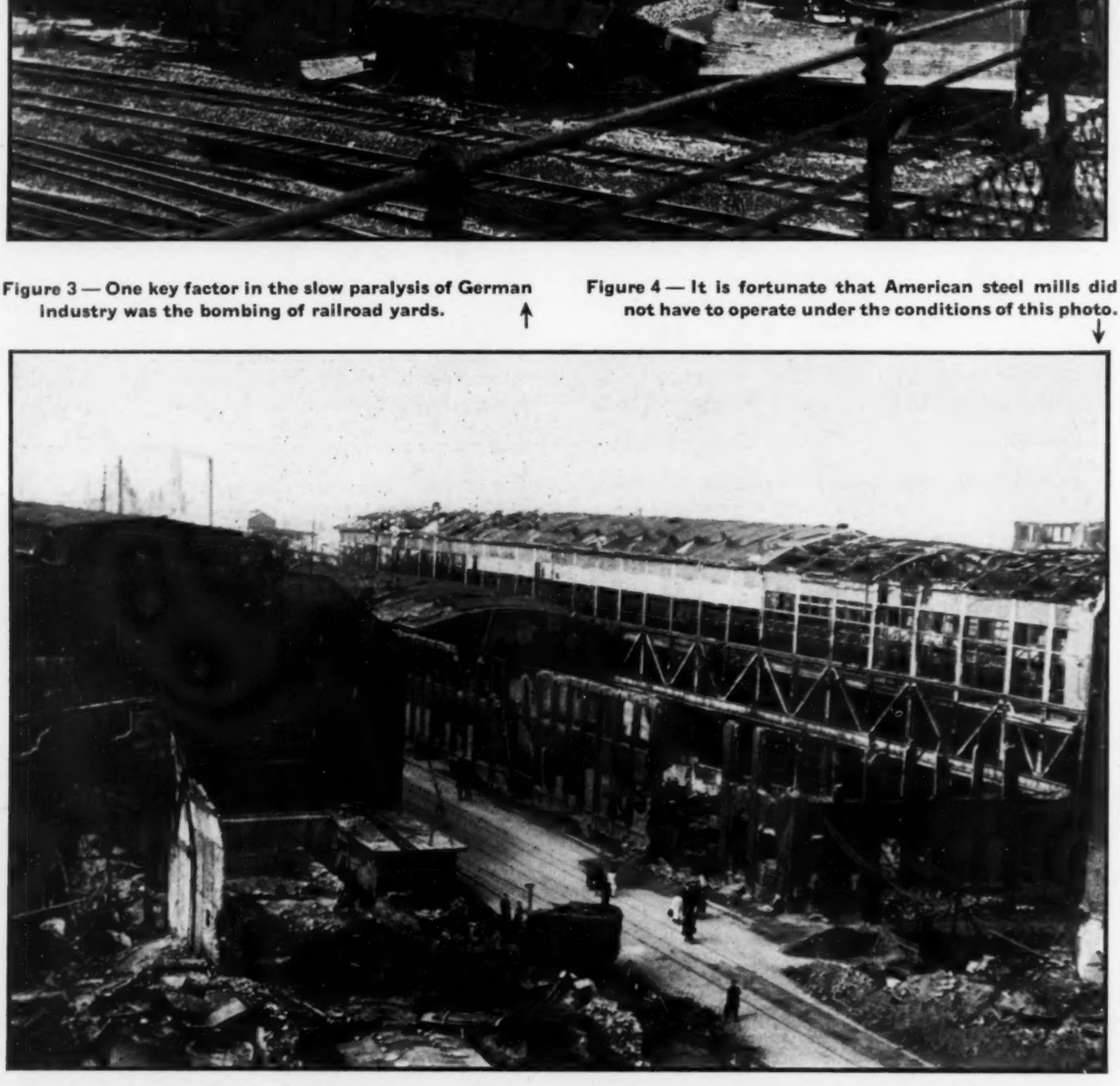
Figure 1 — This bridge was demolished by the Germans by cutting a span on each side of a pier. The remainder of the bridge also thus blocks navigation.

Although cities which were spared destruction are few and far between, an example is Heidelberg, there are a considerable number of manufacturing plants which have survived the war with little more than a single bomb hit, if any. To the extent that an electric motor manufacturer can do any work at all, the military government is sending to it hundreds of street railway motors, electric locomotives, motors for sanitation plants, refrigeration plants and similar public needs and

Figure 2 — A street scene in Frankfurt. This scene is typical of many German cities. It is interesting to note how well the chimneys withstood the bombings.

Figure 3 — One key factor in the slow paralysis of German industry was the bombing of railroad yards.

Figure 4 — It is fortunate that American steel mills did not have to operate under the conditions of this photo.



services. These motors are to be rewound, reconditioned, or even completely rebuilt.

After what I saw in Germany, I know of no quicker way to paralyze a busy city, whether it be Berlin or Pittsburgh, London or New York, than by putting out of commission its electric motors.

The limitations on motor manufacturing on the continent today are principally three in number: (1) The

difficulty encountered in securing and transporting materials such as copper wire, steel sheet, shaft steel, castings and insulation, (2) the lack of fuel, and (3) reduced supervisory personnel.

Although rail lines have been rejoined and truck routes reopened, it should be remembered that the Germans blew their bridges behind them very thoroughly. Today there are still bridges out of commission at important crossings. Temporary bridges and detours complete the main routes but slow down traffic tremendously. For example, single bridges at Cologne, at Dusseldorf and many other cities along the Rhine river are temporary structures, some on pontoons as hurriedly constructed by Army engineers.

Communication with suppliers is limited largely to personal messengers or through military government channels. Telephones and private mail services between cities have been reestablished to only a slight extent.

Department heads and important supervisory personnel are also greatly thinned out. Some individuals have simply disappeared, several are being held for further investigation by the Russians, British or Americans, others identified as Nazi party members are barred from participation in their regular business duties.

In the investigation of German practice, what was found? We in the United States have always thought of German goods as the precise, superior, ingenious products of an unusually scientific country. This is quite true if we are thinking of medical instruments, for example. Army doctors told me of some of the wonderful German equipment they found in the German field and main hospitals. But when it comes to electric motor design and motor manufacturing, have the Germans left American practice standing at the post? By no means. There are some things which they do which are different from what we do. For the most part, however, the reasons which influence them simply do not exist in this country.

In Germany, the size and weight of a motor reflect the general practice of trying to make a little go a long way. From sheer necessity, even before the war, Germany built motors with less available reserve for overload. The Germans cannot get any more out of a pound of copper or iron than we in the United States can. But comparatively low labor costs and high material costs in Germany resulted in emphasis being placed on saving material.

It must be remembered, too, that German industry has been under the war influence for several years; in fact, going away back to their earliest days of preparation. Manufacturers were not permitted to devote time and money to development not directly approved by the government — and the government was interested primarily in armament, tanks and planes. It even neglected to develop automobile trucks to compare with American trucks, although the world at large credited them for a time with having an unexcelled mechanized army. The late General Patton exploded that idea quite completely!

Electric motor builders in Germany have adhered less to standardization and have in some cases disregarded supposedly established national standards. American manufacturers of motors have by common agreement put a lot of information on the nameplate of every motor. In Germany, the motor nameplate may show little more than the horsepower or kilowatt size, the speed and voltage — about as much information as we are accustomed to finding on the nameplate of an electric iron or other household appliance.

This means that the customer cannot know whether he is obtaining a cool running motor that will operate for years or a hot one that may burn up in a week.

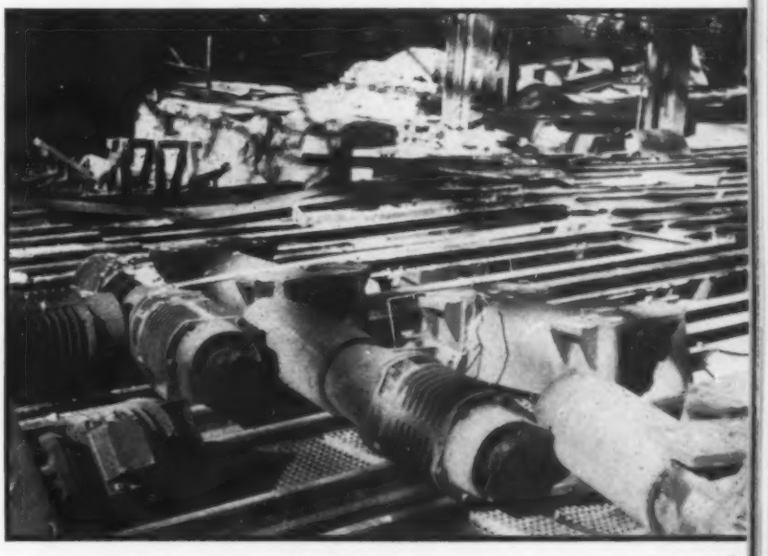
This matter of temperature rise is important to the motor user and to the manufacturer. In the latest German publications, manufacturers have class A and B for insulation, very much as is the standard practice in the United States.

Class A, both open end and closed motors, supposedly are built for a 35 degree ambient temperature and 60 degree rise. Class B motors, both open and closed, are

Figure 5 — Although everything under a bomb hit might be wrecked, machinery a short way from the hit was usually in operable condition.

▲

Figure 6 — Run-out table rollers in damaged steel works.



35 degree room temperature and 80 degree rise. They had already changed these provisions and were expecting to republish them when the war wound up last spring. Room temperature limits were to be raised to 40 degrees, the same as we use here in the United States, but maintaining the same allowable temperature rises, 60 degree for class A and 80 degree for class B. However, one of the big companies over there is going right ahead with its redesign work for its supposedly after the war operations, on the basis of class A motors being 80 degree rise on 35 degree room temperature and class B motors being 130 degree rise on 35 degree room temperature. A lot of substitute materials had to be used during the war, but are not representative of what the industry had prior to the war or, for the most part, appear likely to adopt for after the war service.

The Germans had a lot of aluminum and used it instead of copper for the stator winding of squirrel cage motors. They used iron and aluminum and carbon for bars for commutators of d-c motors. They told us that carbon was successful electrically but very weak mechanically. They tried to make commutator bars for submarines out of carbon but they had great difficulty with the bars chipping before they were even out of the shop. Silver was tried for some small installations.

The use of glass fabric insulation, instead of mica, was developed and adopted by one company for commutator insulation between bars and for "V" rings but with that exception very little other use was made of glass fabric. As a matter of fact, it wasn't generally available to manufacturers on the continent. Another company had gone into the development of a synthetic mica made of quartz but this was experimental and on a relatively small scale.

Without question the electric motor manufacturing industry of Germany has suffered tremendous reverses as a result of the war. As will be seen from some of the accompanying illustrations, technological advances in design were not as great as we might have expected. Critical shortages of materials centered attention on finding acceptable substitutes rather than on pursuing further refinement in design which would have been reflected more directly in motor performance. In fact, the theory that motors were largely expendable seems

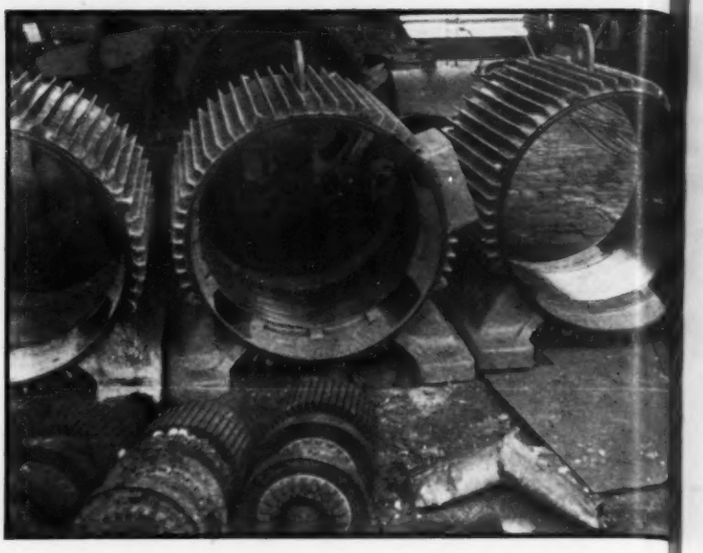
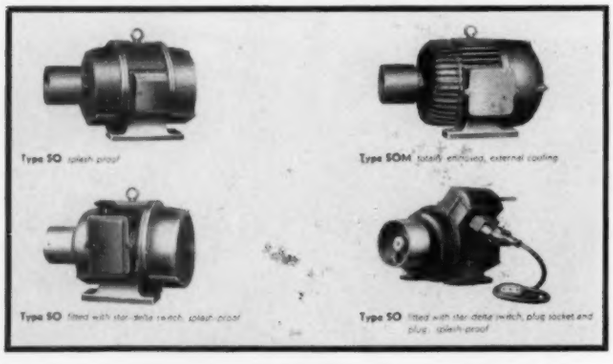


Figure 7 — Motor frames typical of the ribbed, or finned surface designs found in medium and large German totally enclosed motors.

to have governed manufacturing practices during the latter years of the war.

Whether Germany is to rise again as an industrial nation will not, in all likelihood, be settled for some time to come. Meanwhile, the German electric motor industry has its hands full in simply rehabilitating equipment damaged or virtually destroyed as a result of the concentrated bombings delivered by the Allied air fleet in the closing months of the war. It will be some time before these motor manufacturers, even though capable of working at nearly normal efficiency, can take care of the repair work now on the docket. Meanwhile, with rare exceptions, American motor manufacturers appear to have made so much more progress in use of new materials and better application of old ones that there is very little to be adopted from even the best of the German practice.

Figure 8 — Typical German designs of electric motors.


Type SO splash proof
Type SOM totally enclosed, external cooling
Type SO fitted with star-delta switch, splash-proof
Type SO fitted with star-delta switch, plug socket and plug, splash-proof

SENDZIMIR DISCUSSION

(*Continued from page 60*)

points which I have neglected to mention. With regard to the limitations of small work rolls in their torque-carrying capacity, there is a simple answer. It is the four intermediate rolls that we drive, and not the two work rolls. These intermediate rolls are more than twice the diameter of the work rolls, which gives us more than ample torque capacity.

As to roll wear, or better, cost of rolls per ton of strip rolled, this point, far from being a defect, happens to be one of marked advantages of this mill. Small diameter rolls, even if made of high speed steel, are much less expensive than large rolls. Grinding time is very little and usually only about 0.0003 to 0.0005 in. on the diameter is removed at each grinding. It takes only a minute or two to change the rolls and roll changes are not frequent, and we have had no complaints in this respect.

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1. A tough impregnated asbestos braid, resistant to heat, flame, moisture, oil, grease, alkalies and corrosive fumes.
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3. Lubricated varnished cambric for high dielectric strength and added moisture resistance — protected from heat, flame and oxidation by felted asbestos walls.
4. Impregnated asbestos insulation that withstands heat of overloads and aging and won't become brittle, crack, rot or burn.
5. Conductors are perfectly centered in helically applied non-flowing insulation and will always remain so.

ROCKBESTOS A.V.C. 600 VOLT SWITCHBOARD WIRE
(National Electrical Code, Type AVB)

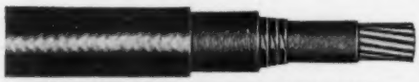
Sizes No. 18 to No. 4/0 AWG with varnished cambric and impregnated asbestos insulation and gray, black, white or colored flameproof braid.

Combine fire insurance and fine appearance in your switchboards with Rockbestos Switchboard Wire. It is fireproof and will not dry out under heat. Sharp, clean bends can be made without cracking as the asbestos wall acts as a cushion under the braid. Rockbestos A.V.C. Hinge Cable and Switchboard Bus Cable have the same characteristics.

ROCKBESTOS A.V.C. 600 VOLT MOTOR LEAD CABLE
(National Electrical Code, Type AVA)

Size No. 18 AWG to 1,000,000 CM insulated with two walls of impregnated asbestos and a high-dielectric varnished cambric insert, with a heavy asbestos braid overall.

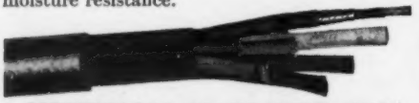
Use this apparatus cable for coil connections, motor and transformer leads exposed to overloads or high ambient temperatures. It makes a permanent installation as it is resistant to heat, flame, oil, grease and moisture.



ROCKBESTOS A.V.C. 600 VOLT POWER CABLE
(National Electrical Code, Type AVA)

Sizes No. 18 AWG to 1,000,000 CM insulated with laminated felted asbestos, varnished cambric, and asbestos braid. Other constructions for service voltages to 5000.

This cable is recommended for power leads of heat-exposed equipment and circuits that run near boilers, steam lines, furnaces, kilns and other hot spots. It withstands high ambient and conductor temperatures and has ample moisture resistance.



ROCKBESTOS A.V.C. 600 VOLT CONTROL CABLE

In one to 19 conductors with individuals insulated like Motor Lead Cable, cotton braid covered and cabled with an asbestos braid over all. Standard strandings AWG No. 12—19/$25 and No. 9—19/$22. Other strandings on order.

Designed for applications requiring a multi-conductor control cable capable of withstanding high temperatures, corrosive fumes, oil, grease and moisture. It also eliminates fire hazard as it will not burn. Used by equipment manufacturers, power companies, steel mills.

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(National Electrical Code, Type AVA)

Sizes No. 18 to 8 AWG insulated with varnished cambric, impregnated felted asbestos and asbestos braid. Sizes 6 to 4/0 have another wall of felted asbestos next to the conductor.

For lighting and control circuits exposed to heat and moisture, oil, grease, corrosive fumes or fire hazard, such as exist around furnaces, ovens, lehrs, soaking pits, boilers, etc., this widely used wire is ideal. Its permanent insulation won't bake brittle, crack, rot, flow or swell.

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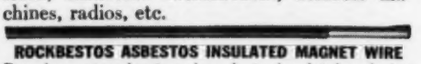
(Underwriters' Type AF)

Sizes No. 10 to 18 AWG stranded plain copper conductor insulated with black or white impregnated felted asbestos—with or without braid.

Rockbestos asbestos insulated fixture wires, approved by the Underwriters' Laboratories, are ideal for lighting fixture wiring because their heat resistant insulation will not bake out under the high socket temperatures developed in modern fixtures. Also used for small motor leads, miniature switchboards, business machines, radios, etc.



ROCKBESTOS ASBESTOS INSULATED MAGNET WIRE

Round, square and rectangular asbestos insulated conductors finished to meet varying winding conditions and coil treatment requirements.

Protect motors against heat-induced breakdowns with class B windings of this heat resisting magnet wire. Leads of Rockbestos A.V.C. Motor Lead Cable will complete the failure-proofing.

ROCKBESTOS A.V.C. 600 VOLT FLEXIBLE CORD

Sizes No. 10 to 18 AWG with two or three conductors insulated with impregnated felted asbestos, varnished cambric, felted asbestos, covered with heavy impregnated asbestos braid.

A heavy duty, high-dielectric, heat and moisture resistant flexible cord used in locomotive cab circuits, high wattage lighting units, floodlights and for leads on apparatus exposed to heat. Specify polarized conductors if desired. For high temperature applications where resistance to moisture is not required specify All-Asbestos insulated constructions.

ROCKBESTOS 300 VOLT HEAT RESISTING DUPLEX FLEXIBLE CORD
(Underwriters' Type AFPD)

Sizes No. 10 to 18 AWG stranded plain copper conductors insulated with impregnated felted asbestos, polarized, twisted together and covered with a cotton braid.

This heat-resisting cord is approved for use in lighting fixtures and is recommended for pendant types as it does not dry out or crack at the socket. Also on apparatus and appliances which develop heat in operation or are used in hot, dry places. Twisted pair, tripled or triplex constructions also available.

ROCKBESTOS ALL-ASBESTOS 600 VOLT RHEOSTAT CABLE
(National Electrical Code, Type AI)

Sizes No. 18 AWG to 1,000,000 CM insulated with a heavy wall of felted asbestos, covered with a rugged asbestos braid finished in black, white or colors.

Use this cable for wiring rheostats, switchboards, elevator and locomotive control panels and equipment exposed to heat, fumes or fire hazard — also for open power circuits in hot, dry locations. For flexible conductor specify Rockbestos All-Asbestos Flexible Apparatus Cable — for solid conductor, Rockbestos All-Asbestos Rheostat Wire.

ROCKBESTOS PRODUCTS CORP., 129 Nicoll St., New Haven 4, Conn.

125 STANDARD TYPES

ROCKBESTOS

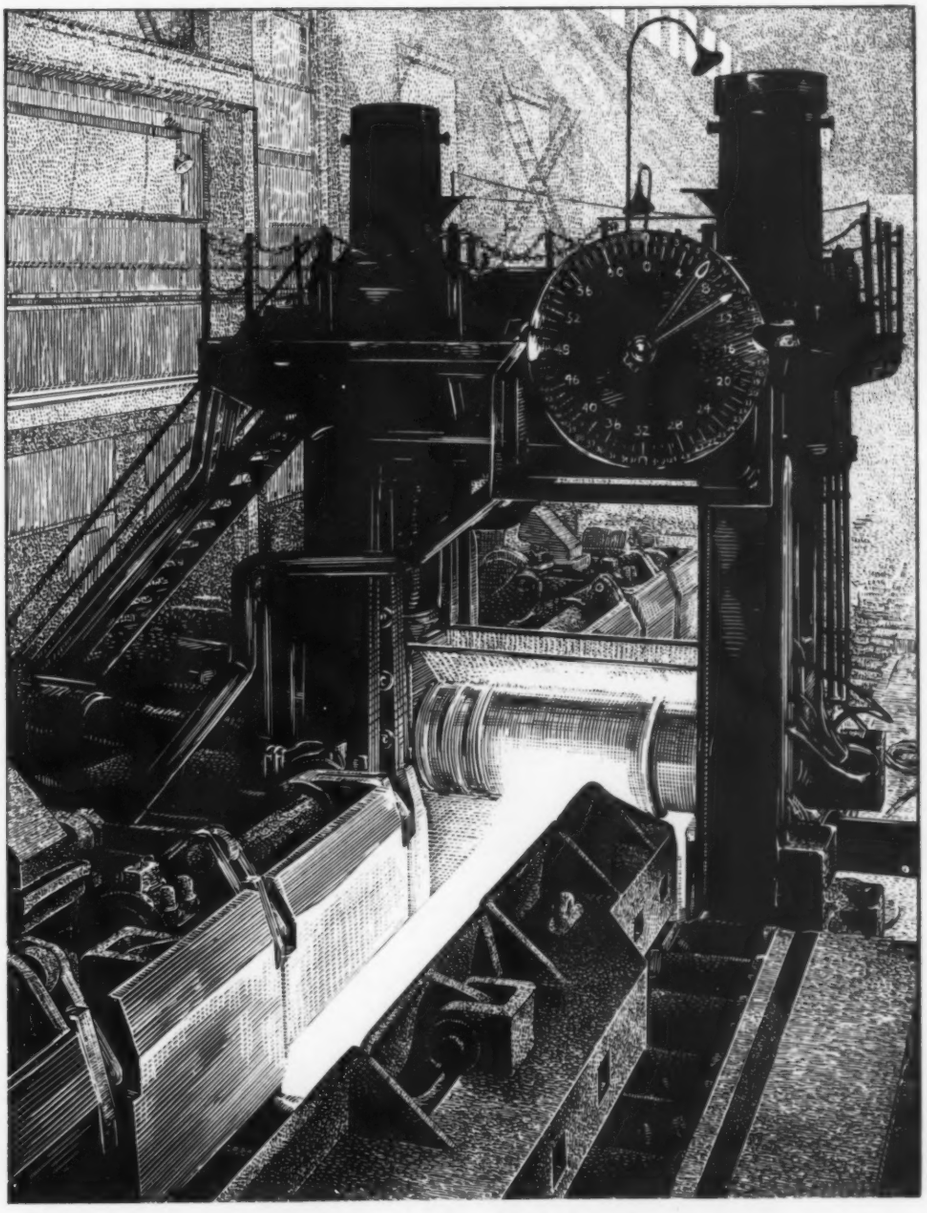
The Wire with Permanent Insulation

Association of Iron and Steel Engineers

ANNUAL SPRING CONFERENCE

Sponsored by the

ROLLING MILL COMMITTEE



MONDAY · TUESDAY · MAY 6-7, 1946 · CONGRESS HOTEL · CHICAGO, ILL.

LOUIS MOSES

C. E. PRITCHARD

R. E. BEYNON

ALEX MONTGOMERY,

C. P. HAMMOND

F. E. CREVER

P. L. HAAGER

J. N. IMEL

A. J. LANGHAMMER

C. W. BARRETT

J. G. MEENAN

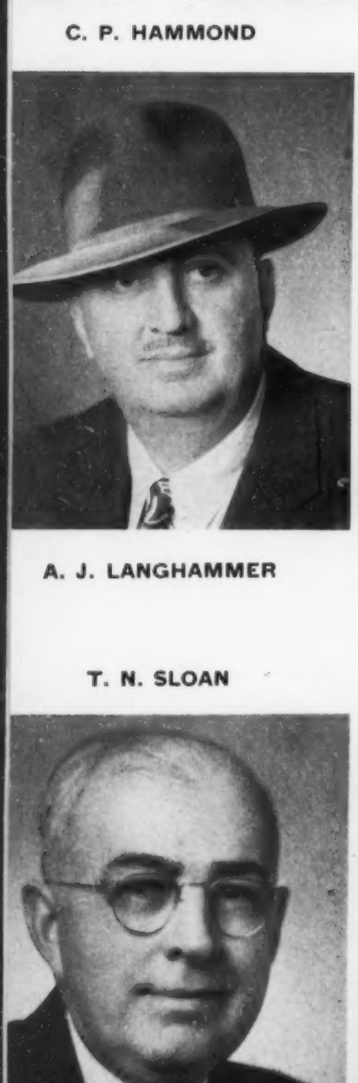
C. W. BRUCE

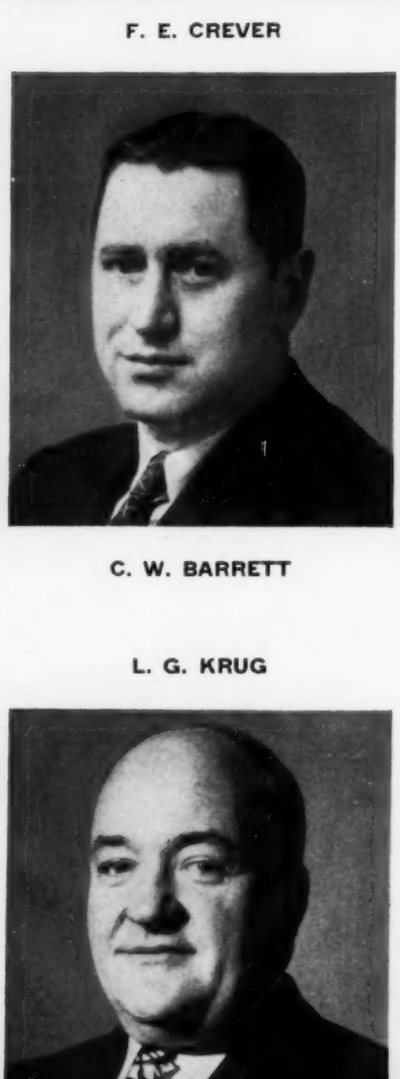
T. N. SLOAN

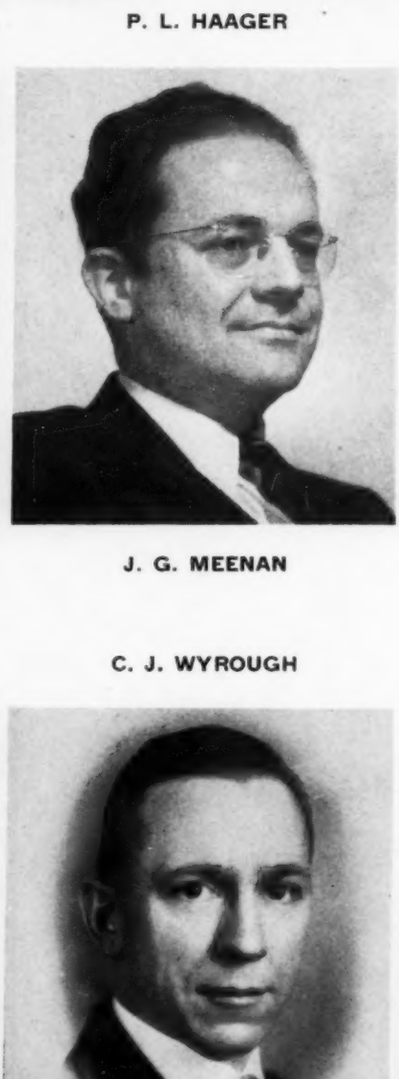
L. G. KRUG

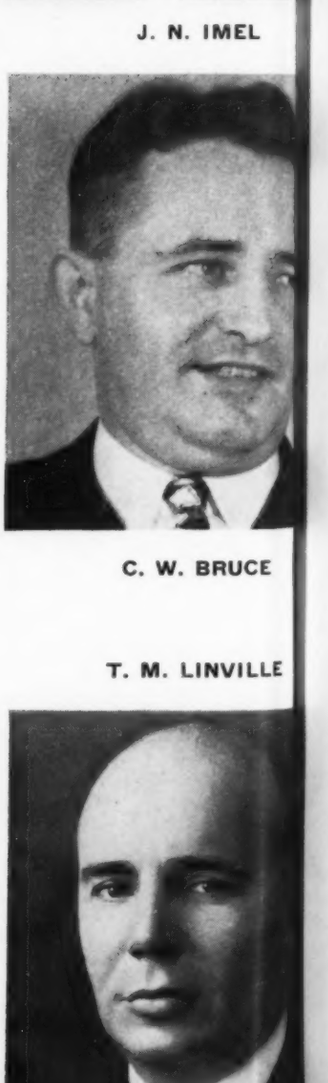
C. J. WYROUGH

T. M. LINVILLE









Monday, May 6

9:00 a. m. Registration — Florentine Lobby, Third Floor

9:15 a. m. Technical Meeting — Florentine Room

Co-Chairmen:

Alex Montgomery, Jr.
Assistant General Superintendent
Carnegie-Illinois Steel Corporation
Duquesne, Pennsylvania

C. W. Barrett
Roll Designer
Republic Steel Corporation
Chicago 17, Illinois

"The Art of Rolling Rounds," by C. P. Hammond, Superintendent Rolling Mills, Atlas Steels Limited, Welland, Ontario, Canada.

"Roll Design for Die Rolling," by T. N. Sloan, Die Roll Designer, Republic Steel Corporation, Buffalo, New York.

"Design of Mill Tables," by J. G. Meenan, Design Engineer, United Engineering and Foundry Company, Pittsburgh, Pennsylvania.

2:00 p. m. Technical Meeting — Florentine Room

Co-Chairmen:

C. E. Pritchard
Lubrication Engineer
Republic Steel Corporation
Cleveland, Ohio

D. N. Evans
Lubrication Engineer
Inland Steel Company
East Chicago, Indiana

Symposium — Rolling Mill Bearings

"Roller Bearings," by Paul Haager, Assistant Chief Engineer, Industrial Division, The Timken Roller Bearing Company, Canton, Ohio.

"Metallic Bearings," by H. L. Smith, Federated Metals Division, American Smelting and Refining Company, Pittsburgh, Pennsylvania.

"Composition Bearings," by W. A. Rankin, Engineering Division Bearings and Gears, Gatke Corporation, Chicago, Illinois.

"Metal Powder Self-Lubricating Bearings," by A. J. Langhammer, President, Amplex Division, Chrysler Corporation, Detroit, Michigan.

"Bearing Seals," by L. G. Krug, Chicago Rawhide Manufacturing Company, Chicago, Illinois.

7:00 p. m. Dinner — Casino Room

L. R. MILBURN

A. J. FISHER

C. H. WILLIAMS

R. W. GRAHAM

Tuesday, May 7

9:30 a. m. Inspection Trip — Republic Steel Corporation, South Chicago, Illinois

2:00 p. m. Technical Meeting — Florentine Room

Co-Chairmen:

Louis Moses, Superintendent
Rail and Roll Mills
Bethlehem Steel Company
Sparrows Point, Maryland

Ross E. Beynon
Roll Engineer
Carnegie-Illinois Steel Corp.
Chicago, Illinois

C. J. Wyrough, Superintendent
Steam Efficiency and Combustion Depts.
Jones & Laughlin Steel Corporation
Pittsburgh, Pennsylvania

C. W. Bruce
Combustion Engineer
Republic Steel Corporation
Chicago, Illinois

"Speed Stability for Continuous Mills," by F. E. Crever, Steel Mill Division, Industrial Engineering Divisions, and T. M. Linville, Motor and Generator Engineering Division, Apparatus Department, General Electric Company, Schenectady, New York.

"A New Soaking Pit Design," by Norman Urquhart, Fort Pitt Bridge Company, Canonsburg, Pennsylvania.

"Modern Steel Providing Methods," by R. W. Graham, Assistant Division Superintendent, Slab and Plate Mills, Carnegie-Illinois Steel Corporation, Munhall, Pennsylvania.

"Bar Mill Housings and Equipment," by J. N. Imel, General Foreman, No. 16 and 17 Mills, Jones & Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

TO THE

MEN OF THE STEEL INDUSTRY

Perhaps never before has the interchange of knowledge been of such vital importance to the iron and steel industry. Faced with a variety of conditions which necessitates the use of utmost economy in operations it is essential to learn and utilize every new idea that will contribute to more efficient operation.

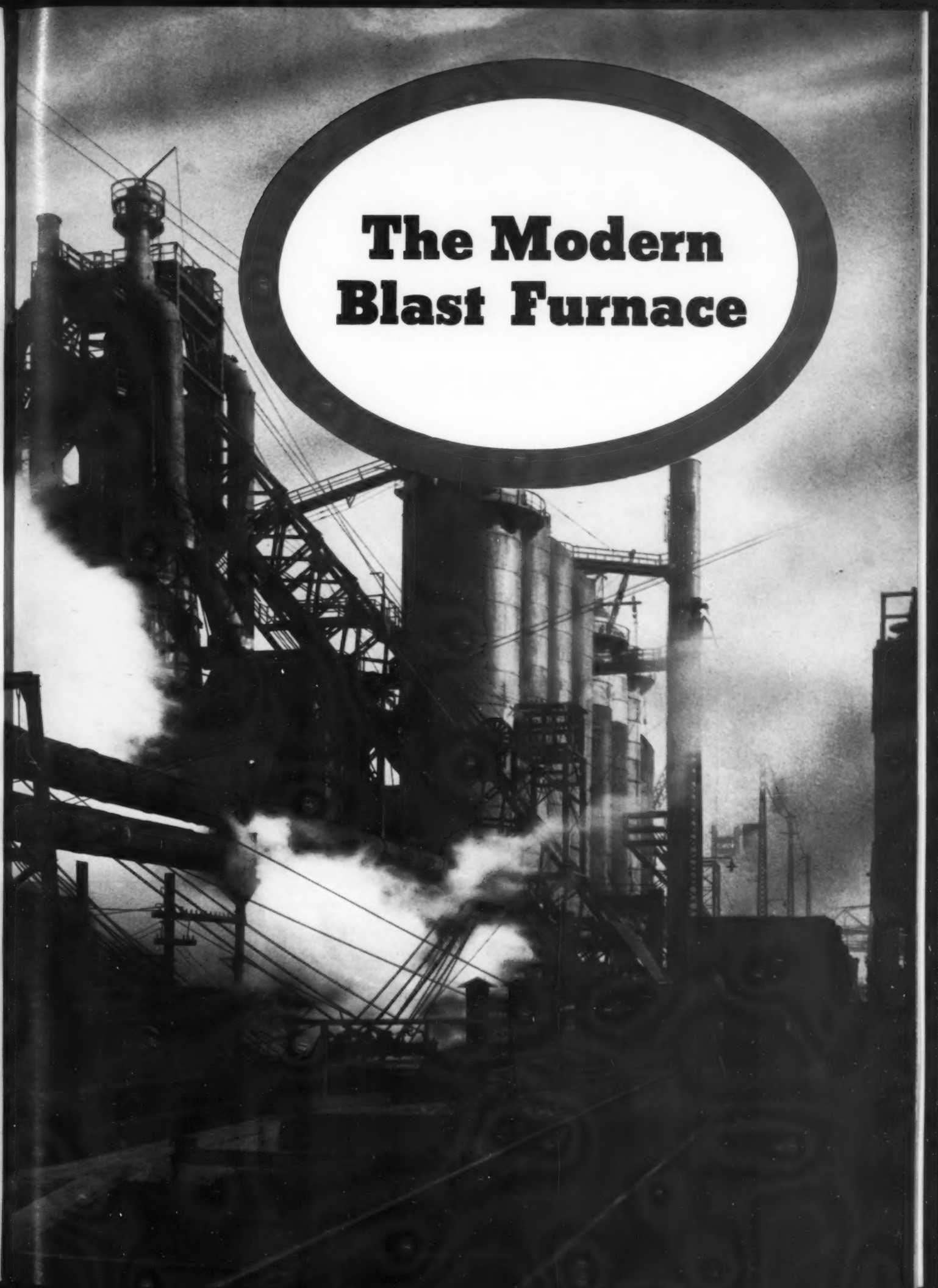
In scheduling this conference the Association of Iron and Steel Engineers presents an opportunity for an interchange of ideas which cannot fail to benefit the industry, and I am pleased to be able to extend to you a cordial invitation to attend.

Freeman H. Dyke

PRESIDENT

ASSOCIATION OF IRON AND STEEL ENGINEERS

1010 EMPIRE BUILDING PITTSBURGH, PENNA.


The Modern
Blast Furnace

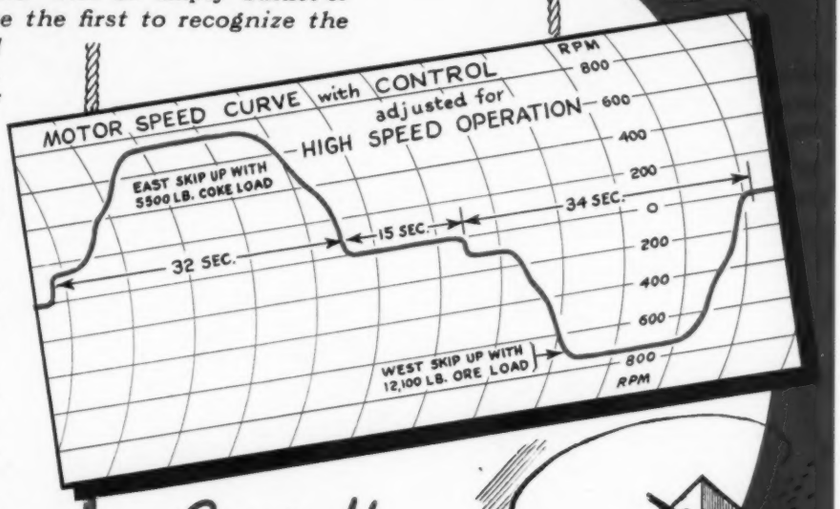
4 BIG ADVANTAGES IN SKIP HOIST OPERATION WITH EC&M LINE-ARC CONTACTOR CONTROL

1 *Adjustable Control* allowing up to double the running speed on the straight part of the track for reduced charging-time. Full field strength and maximum torque for acceleration, and at slow-down for accurate stopping—either with an empty bucket or capacity ore load. (*EC&M were the first to recognize the advantages of adjustable field control to speed up the skip-hoist on the straight part of the track.*)

2 *Low Initial Investment*—and low stand-by renewal part inventory.

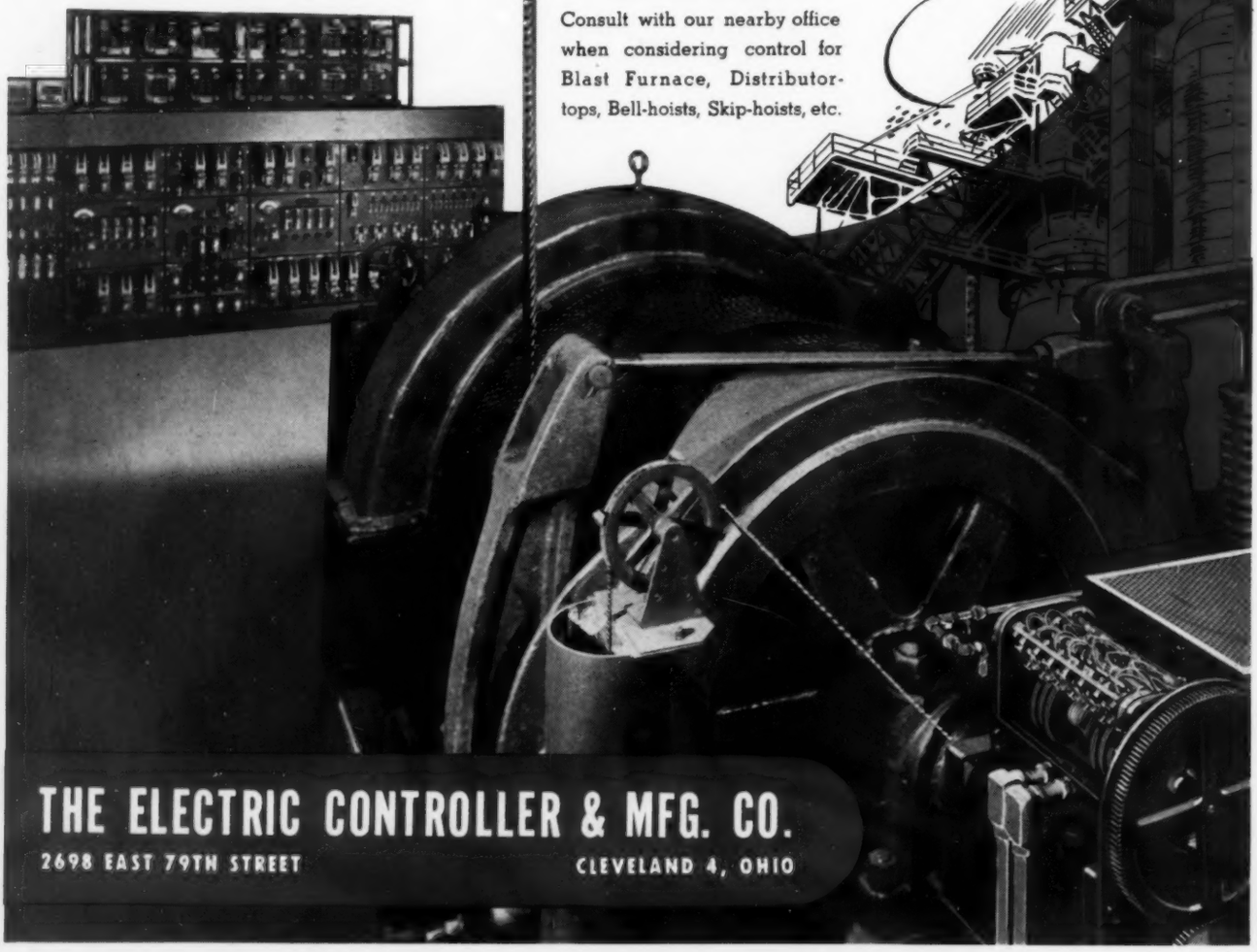
3 *Simple Construction Easily Inspected*—with minimum labor and up-keep expense.

4 *Safe, Smooth Operation* under all conditions of load. The accompanying curve shows this clearly and is typical of the economical, smooth and efficient operation obtained with this control.



Consult

Consult with our nearby office when considering control for Blast Furnace, Distributor-tops, Bell-hoists, Skip-hoists, etc.



THE ELECTRIC CONTROLLER & MFG. CO.

2698 EAST 79TH STREET CLEVELAND 4, OHIO

"TOOL STEEL" PROCESS

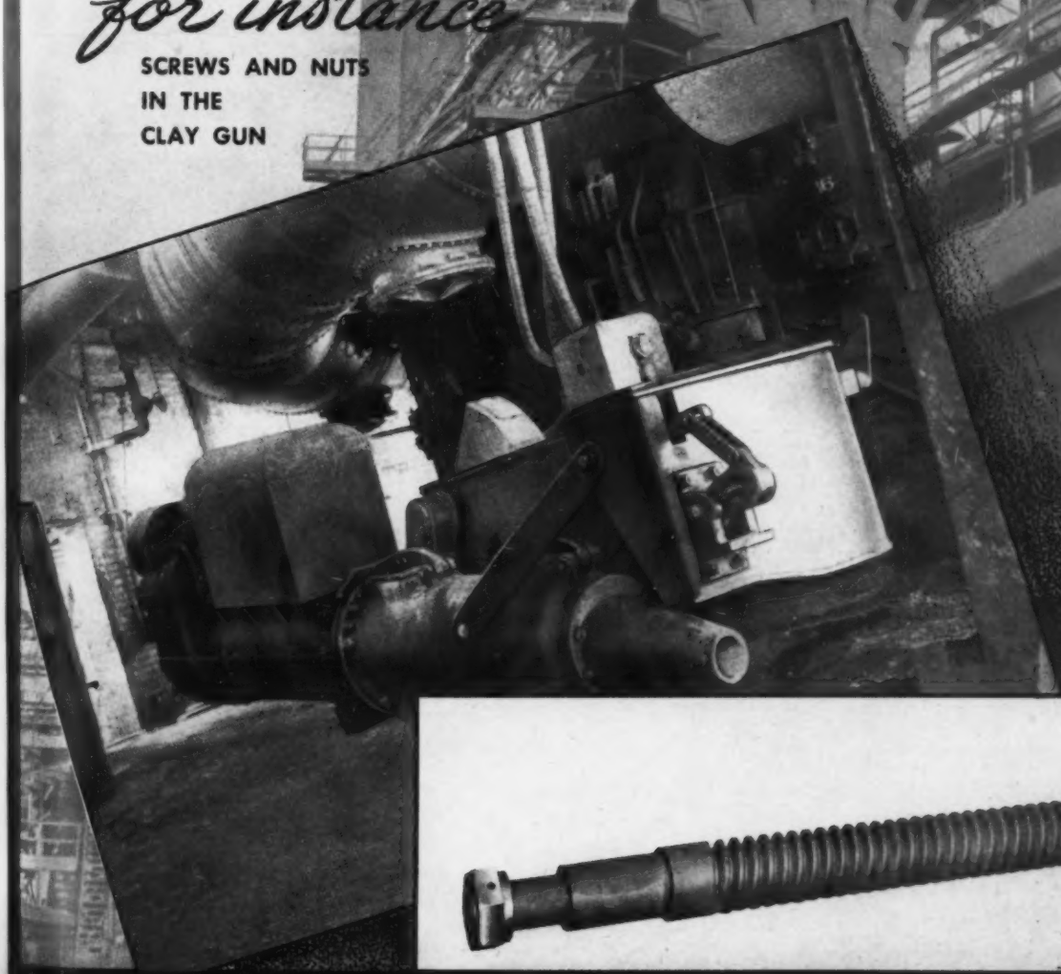
BREAKS THE RECORDS

FOR LONG LIFE
AND TROUBLE FREE
SERVICE . . .

ON TOUGH JOBS AROUND A BLAST FURNACE

for instance

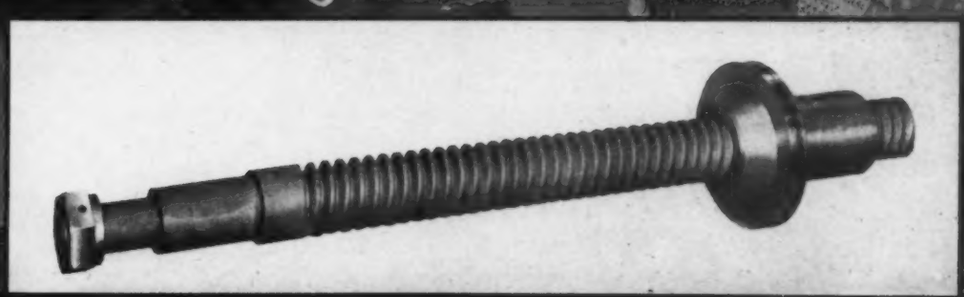
SCREWS AND NUTS
IN THE
CLAY GUN



also . . .

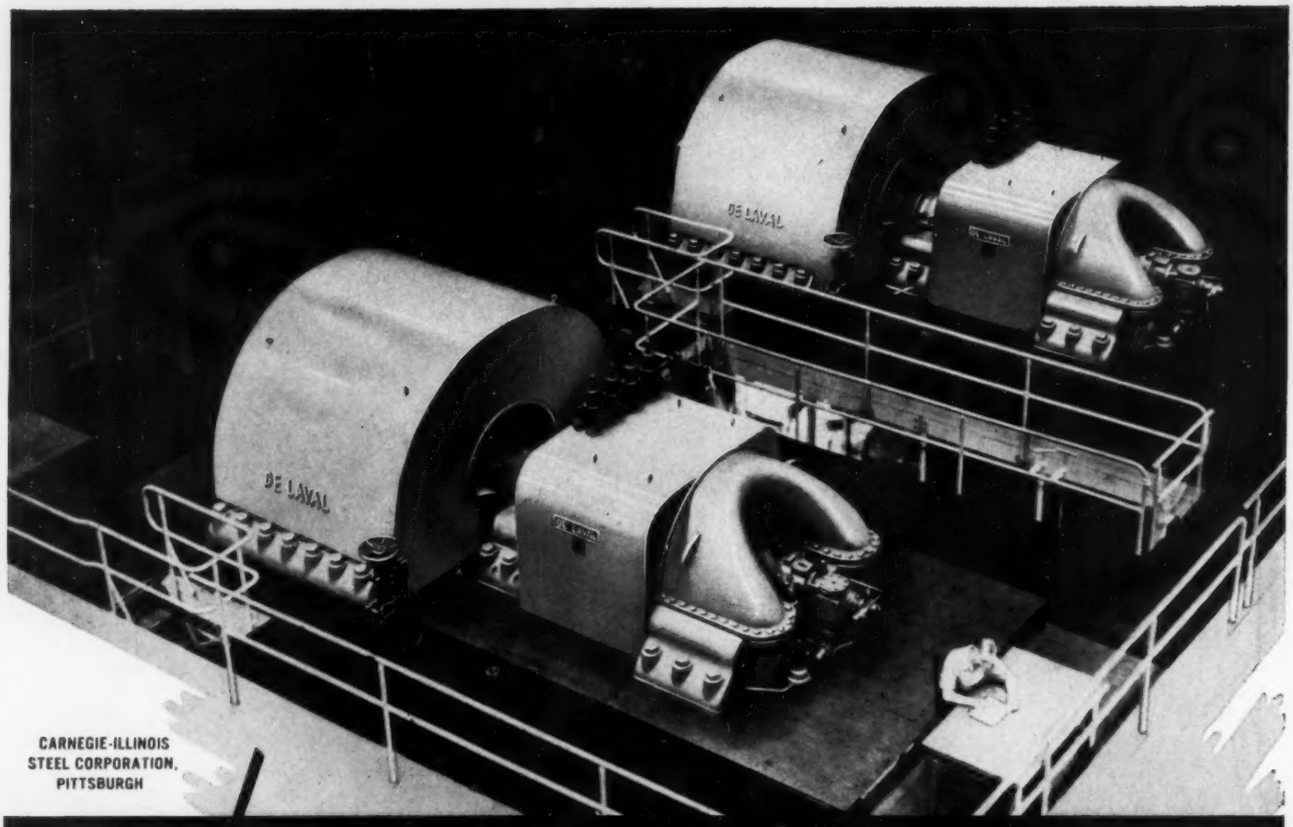
SKIP CAR
WHEELS

SHEAVE
WHEELS
FOR
BLAST
FURNACES



THE TOOL STEEL GEAR & PINION COMPANY

CINCINNATI 16, OHIO



CARNEGIE-ILLINOIS STEEL CORPORATION, PITTSBURGH

WORLD'S RECORD BROKEN AGAIN!

by FURNACE EQUIPPED WITH DE LAVAL BLOWERS

For the second time in two years, the world's record has been broken for pig iron production from a single furnace served with De Laval turbine-driven blast furnace blowers.

During the month of July, 1945 the No. 2 Furnace of the Edgar Thompson Works of the Carnegie-Illinois Steel Corp. produced a record-breaking 50,590 tons.

The De Laval blowers at the Edgar Thompson Works, with a capacity of 97,800 c.f.m. against 30 p.s.i., were designed for the highest maximum steam pressure (700 p.s.i) and temperature (825 F.) ever used for this service.

CONSULT THE DE LAVAL STEAM TURBINE CO. FOR CENTRIFUGAL BLOWERS AND COMPRESSORS OF ADVANCED DESIGN.

3833

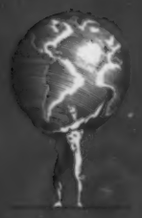
TURBINES • HELICAL GEARS
WORM GEAR SPEED REDUCERS
CENTRIFUGAL PUMPS • CENTRIFUGAL BLOWERS and COMPRESSORS • IMO OIL PUMPS

DE LAVAL

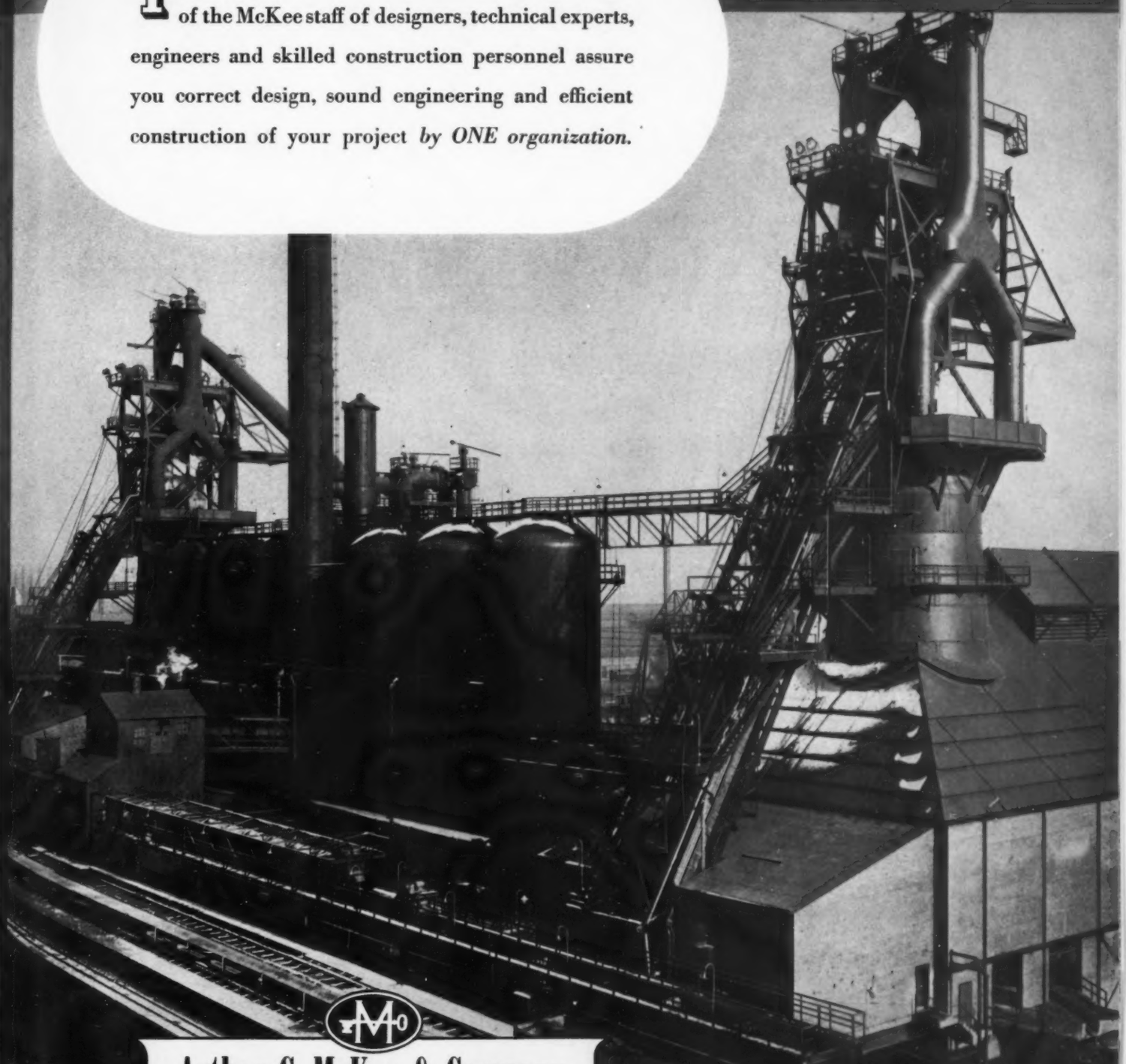
STEAM TURBINE COMPANY · TRENTON 2, NEW JERSEY

SALES OFFICES ATLANTA • BOSTON • CHARLOTTE • CHICAGO • CLEVELAND • DENVER DETROIT • HELENA • HONOLULU • HOUSTON KANSAS CITY • LOS ANGELES • MANILA MONTREAL • NEW HAVEN • NEW ORLEANS NEW YORK • PHILADELPHIA • PITTSBURGH ROCHESTER • ST. PAUL • SALT LAKE CITY • SAN FRANCISCO • SEATTLE • TORONTO • TULSA VANCOUVER • WASHINGTON, D.C. • WINNIPEG And Cities in Central and South America

INDIVIDED RESPONSIBILITY IN ONE ORGANIZATION



THE specialized knowledge and broad experience of the McKee staff of designers, technical experts, engineers and skilled construction personnel assure you correct design, sound engineering and efficient construction of your project *by ONE organization.*



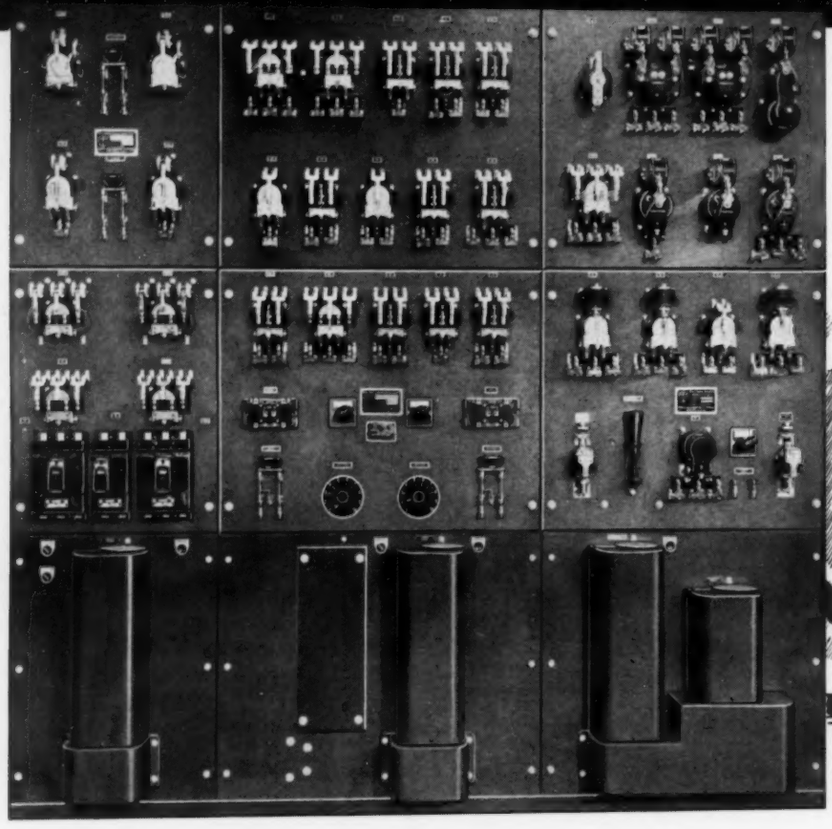
Arthur G. McKee & Company

★ *Engineers and Contractors* ★

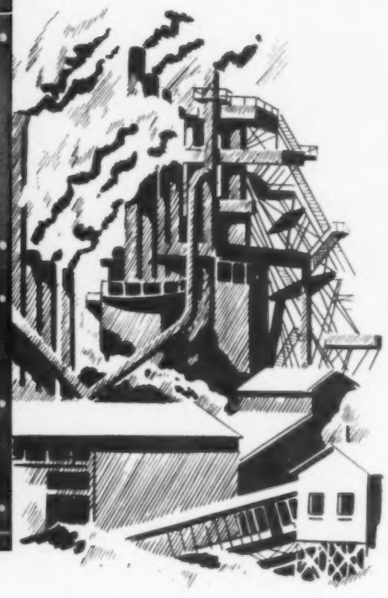
2300 CHESTER AVENUE · CLEVELAND, OHIO

30 Rockefeller Plaza, New York, N.Y.
Commerce Building, Houston, Texas

FREYN DESIGN and CLARK CONTROLS – the ideal combination for Blast Furnaces



Front view of Freyn-Design — Clark-Equipped Charging Control Panel.



● Automatic control of blast furnace charging is effectively accomplished by the three-panel installation shown above.

Center panel (charging control panel) is the master mind for controlling motor-driven skip-hoists, revolving distributor, small and large bell hoist. The scale car operator pushes a button when the skip is loaded. This initiates the operations, interlocking them so that they can only be performed in correct sequence. Panel at right is a Freyn-Design Reversing Distributor control, governing the functioning of revolving distributor at top of furnace. Panel at left provides control for Freyn-Design Dual Stockline Recorder. This governs operation of two test rods which measure level of material charged into furnace. Control equipment for an equalizer valve interlocked with bell hoists, is also on this panel.

Freyn Engineering plus Clark Control equipment are successfully operating in representative installations all over the world.

THE CLARK CONTROLLER CO.

1146 EAST 152nd ST., CLEVELAND 10, OHIO • EVERYTHING UNDER CONTROL

FREYN DESIGN

...IS A HALL-MARK OF GOOD ENGINEERING

★ COMPETENCY

★ INTEGRITY

★ RESPONSIBILITY

Through three decades Freyn Design has been a prime factor in the evolution of the Modern American Blast Furnace

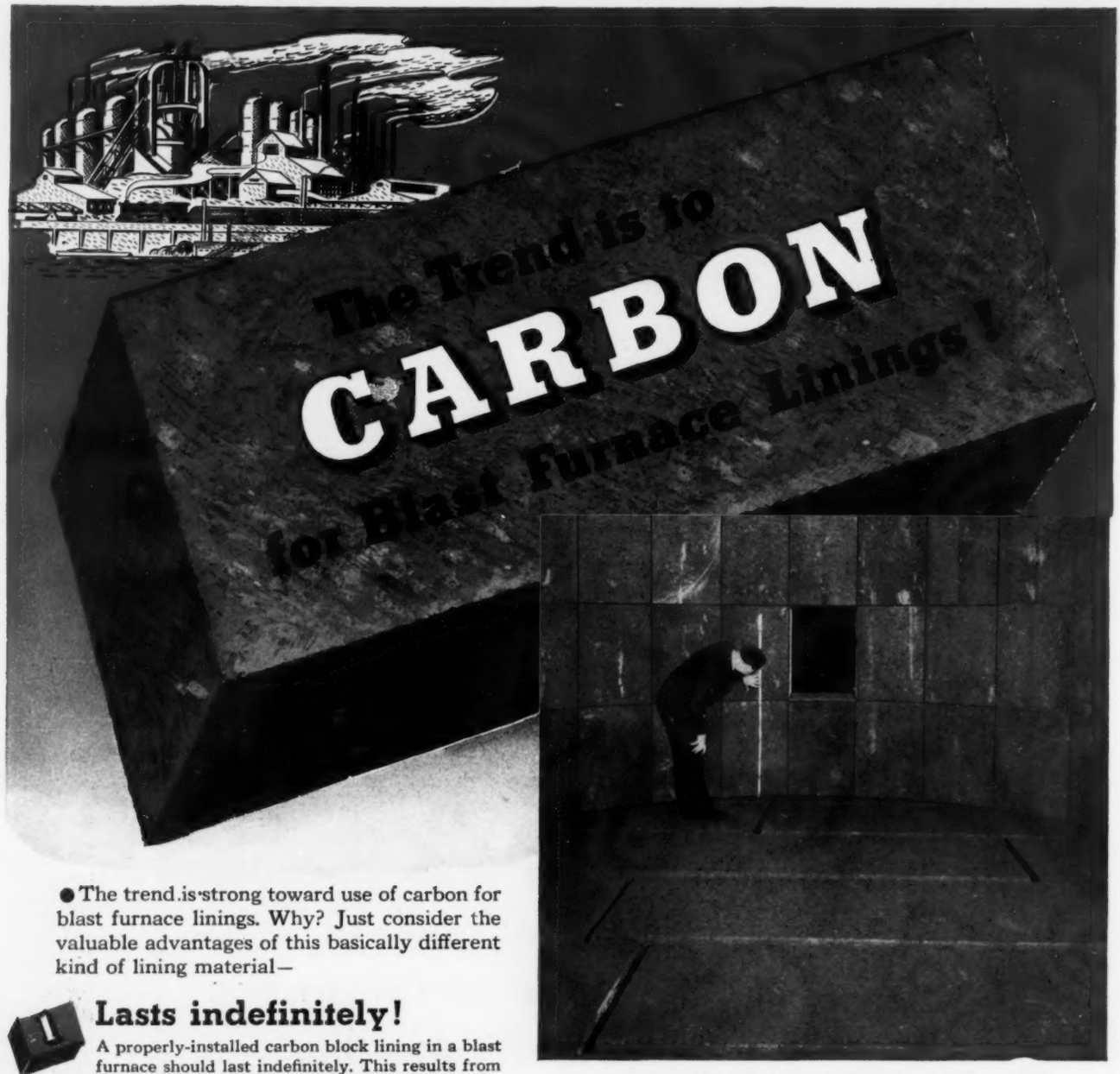
1914 • 1946

Freyn Engineering Company

CONSTRUCTORS — ENGINEERS — SPECIALTIES

58 EAST WASHINGTON STREET · CHICAGO 2, U.S.A.

ASSOCIATED WITH:
ASHMORE, BENSON, PEASE & CO. LTD., STOCKTON-ON-TEES, ENGLAND.



● The trend is strong toward use of carbon for blast furnace linings. Why? Just consider the valuable advantages of this basically different kind of lining material—

1 Lasts indefinitely!

A properly-installed carbon block lining in a blast furnace should last indefinitely. This results from the remarkable physical properties of carbon: no melting point, low thermal expansion, highly resistant to thermal shock, not wet by molten metals, immune to metal and slag attack, mechanical strength maintained at high temperatures.

2 No Salamander!

Years of experience with carbon linings bears this out. Consider what a saving this feature, alone, can mean to you.

3 Fast, easy to install!

One carbon block can take the place of from 50 to 1000 nine-inch firebrick, depending upon the size of the block. Overall installation time is thus greatly reduced.

Interior of hearth lining looking toward iron notch. Blocks may be of any size desired up to 24x30x180 in.

4 Economical in long run!

Operating experience is proving that carbon linings are definitely more economical in the long run . . . as is evident from the features outlined at left.

WHATEVER YOUR PROBLEM — CONSIDER CARBON OR GRAPHITE

Get more details:

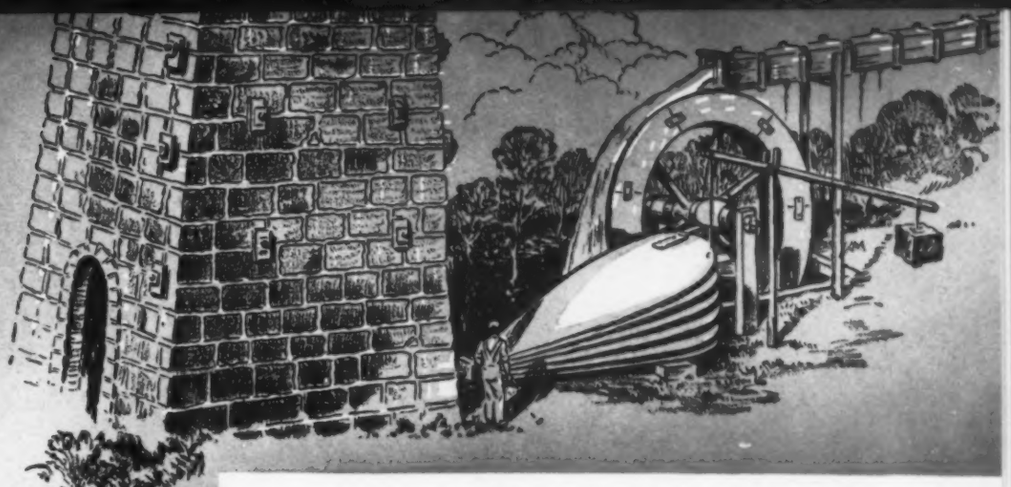
Engineers at National Carbon Company, Inc., will be glad to supply you with full available information on all phases of installing a carbon lining. Write today **to Dept. IS.**

NATIONAL CARBON COMPANY, INC.

Unit of Union Carbide and Carbon Corporation
The word "National" is a registered trade-mark of National Carbon Company, Inc.

UCC

30 East 42nd Street, New York 17, N. Y.
Division Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco



20 HP of water power converted to air power, based on sketches of a cold blast charcoal furnace worked in the early part of the 19th century. (From Two Centuries of Iron Smelting in Pennsylvania by Richard Peters, Jr.).

The AIR ARM of INDUSTRY

Since man first blew or fanned a faltering fire, he has been experimenting with compressed air as a means of aiding combustion. The ingenious water-wheel bellows was one of his early efforts—one of many steps toward present day record-breaking production of metals.

Today it is the Turbo Blower that furnishes the air blast. These compact, centrifugal machines compress huge volumes of combustion air for the nation's furnaces and converters. Since 1913, when the first I-R Blast Furnace Turbo Blower was installed, Ingersoll-Rand has maintained its leadership in this field.

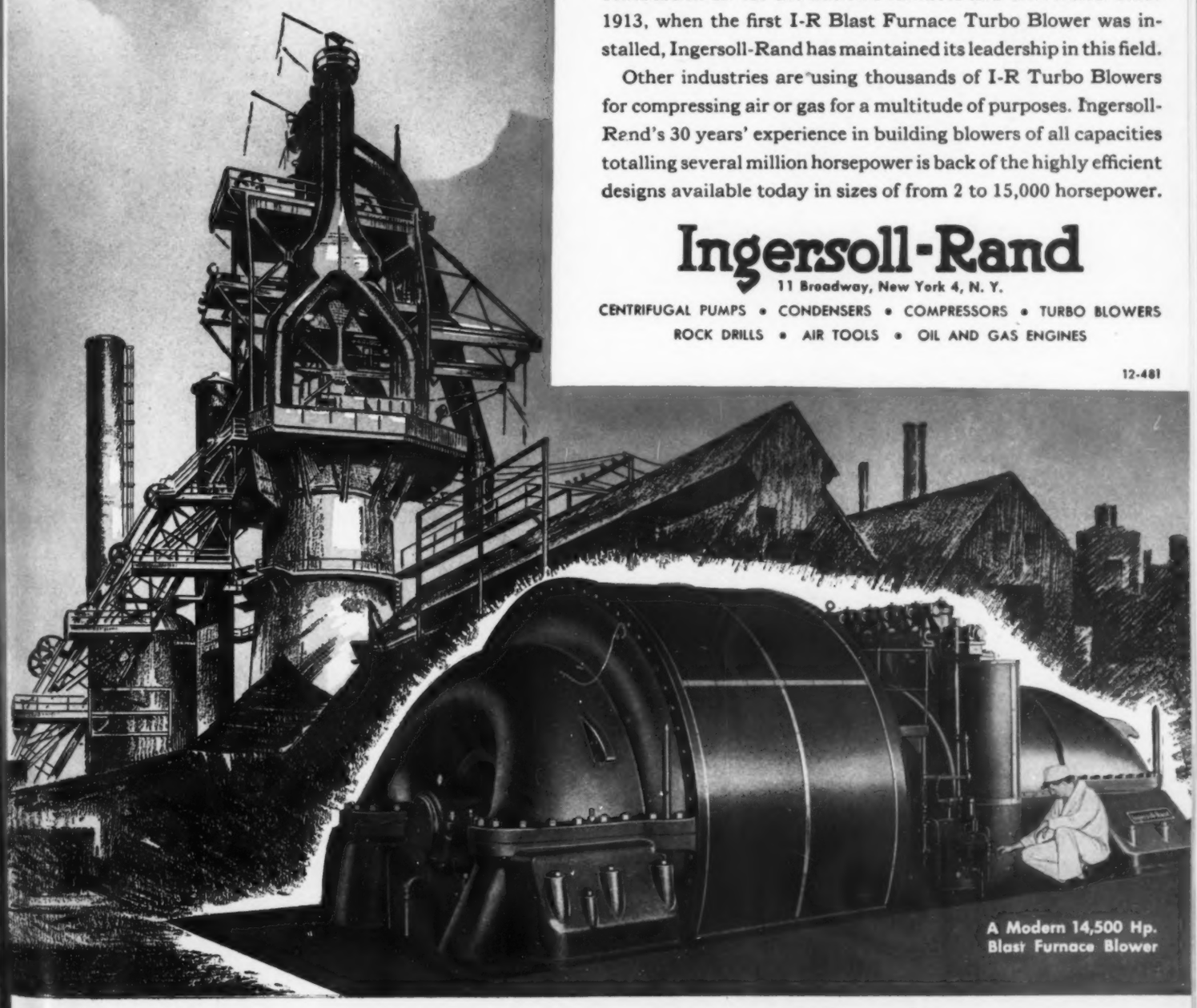
Other industries are using thousands of I-R Turbo Blowers for compressing air or gas for a multitude of purposes. Ingersoll-Rand's 30 years' experience in building blowers of all capacities totalling several million horsepower is back of the highly efficient designs available today in sizes of from 2 to 15,000 horsepower.

Ingersoll-Rand

11 Broadway, New York 4, N. Y.

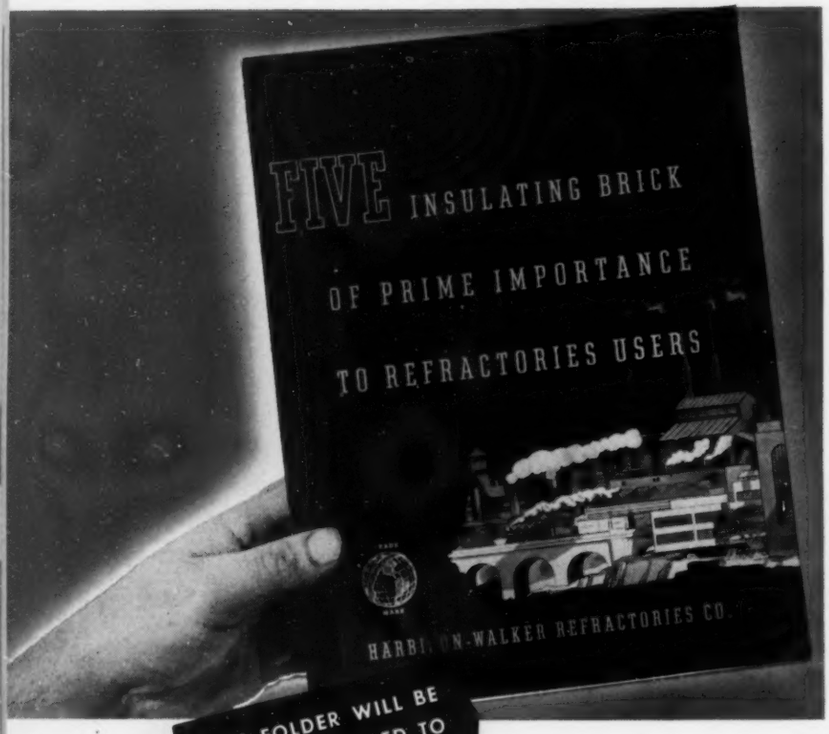
CENTRIFUGAL PUMPS • CONDENSERS • COMPRESSORS • TURBO BLOWERS
ROCK DRILLS • AIR TOOLS • OIL AND GAS ENGINES

12-481



A Modern 14,500 Hp. Blast Furnace Blower

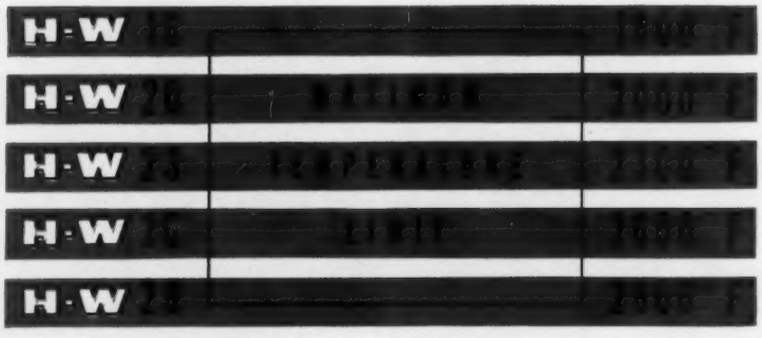
INSULATE WITH SAFETY at any temperature



THIS FOLDER WILL BE PROMPTLY MAILED TO YOU UPON REQUEST

For insulating the refractory linings of industrial furnaces, many combinations of insulating fire brick and refractory fire brick are possible.

Harbison-Walker, with complete lines of both insulating fire brick and refractory fire brick, can furnish the correct combination for any service requirements.



In the research and manufacturing developments preceding the introduction of each of these five brands, Harbison-Walker has achieved balance between the important and interrelated properties of strength and thermal efficiency. Light weight, essential to high insulating value and low heaf storage capacity have been attained without undue sacrifice of the mechanical strength necessary to insure minimum loss through breakage in transit and in normal handling on the job. Brick masons prefer to handle Harbison-Walker brick, and combustion engineers recognize the efficiency and economy resulting from their use.

HARBISON-WALKER REFRACTORIES COMPANY
AND SUBSIDIARIES
WORLD'S LARGEST PRODUCERS OF REFRACTORIES
GENERAL OFFICES - PITTSBURGH, PENNA.

REG. U.S. PAT. OFF.

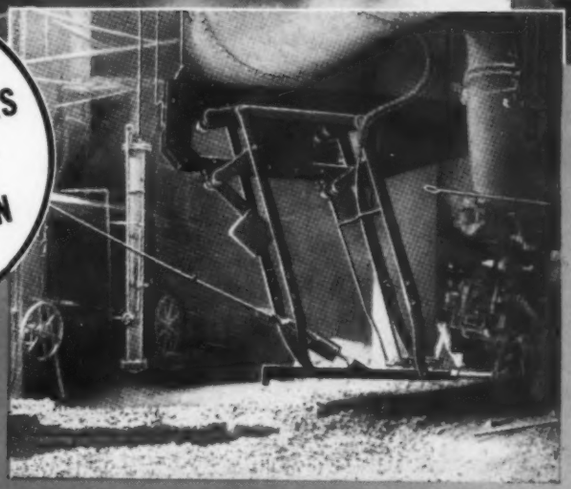
Bailey PRECISION ENGINEERED

BLAST FURNACE EQUIPMENT...

BAILEY ELECTRIC PLUNGER CLAY GUN

2

"BAILEY-PROVED" ALLIES OF IRON PRODUCTION



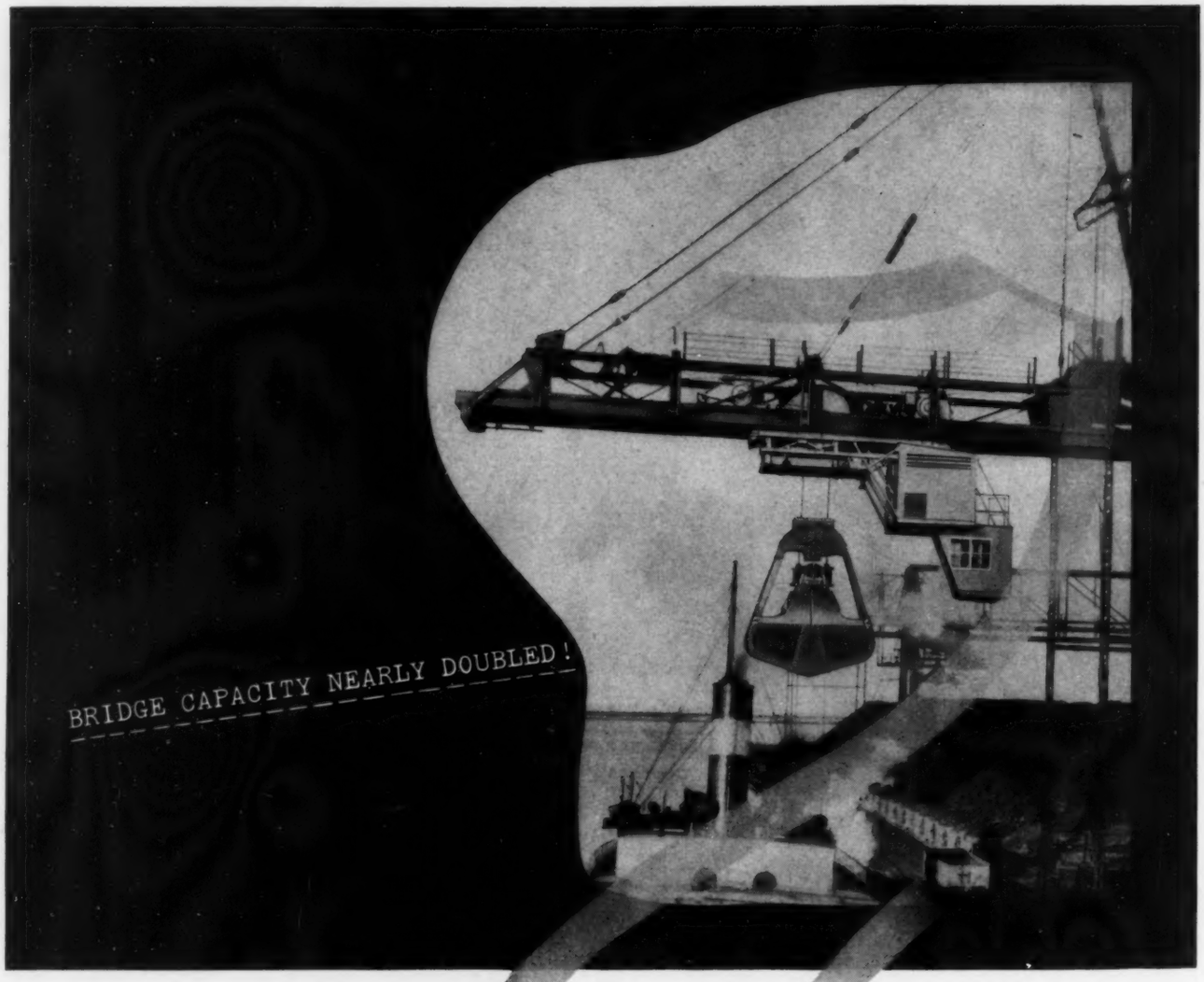
BAILEY CINDER NOTCH STOPPER

The Bailey Electric Clay Gun is replete with power and strength for a mighty task! What *really* counts is its performance . . . dependable performance in stopping the tapping hole under the most gruelling conditions.

The Bailey Cinder Notch Stopper readily eliminates hazards at the cinder notch . . . continually plugging the cinder notch quickly, economically and safely.

Get the BAILEY facts!

WILLIAM M. BAILEY COMPANY *Engineers* **PITTSBURGH**



To increase the bucket load capacity from 13,000 pounds to 24,000 pounds, Dravo designed a special light-weight man trolley, which, in combination with an aluminum bucket, made the 85% boost in pay load possible within the limits of the existing coal bridge structure.

Special problems in the design of materials handling installations receive special and skillful attention at Dravo. Bulletin 216, containing many interesting examples of special purpose installations is available on request. Address Dravo Corporation, Pittsburgh, Pa.

DRAVO

GENERAL CONTRACTING
TOWBOATS AND BARGES
MACHINERY AND EQUIPMENT
MATERIALS HANDLING
SAND AND GRAVEL
RIVER FREIGHT TRANSPORTATION
POWER PLANTS
TERMINAL EQUIPMENT
ENGINEERING CONSTRUCTION
HEATING SYSTEMS

BLAST FURNACE COPPER CASTINGS

Bosh Plates
Mantle Plates
Cinder Notches
Tuyeres
Tuyere Coolers
Hot Blast Valves
and Valve Seats

SMEETH-HARWOOD COMPANY

2401-09 West Cermak Road, Chicago 8, Illinois

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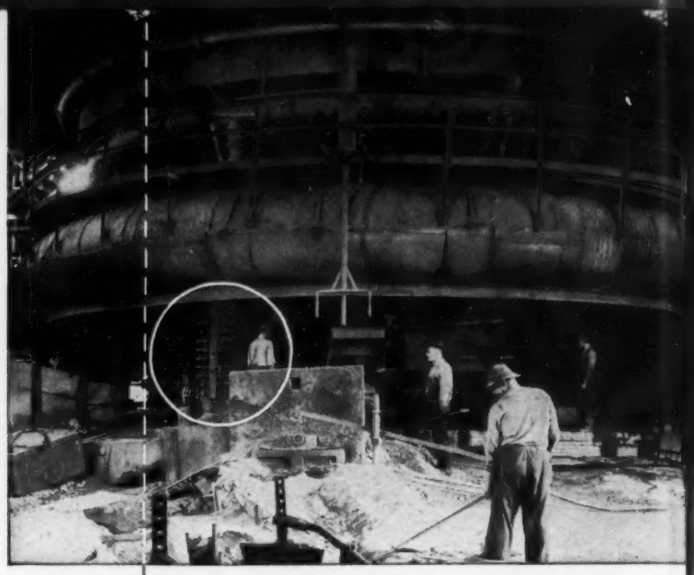

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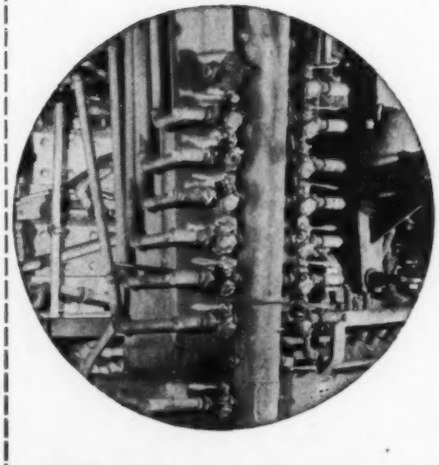

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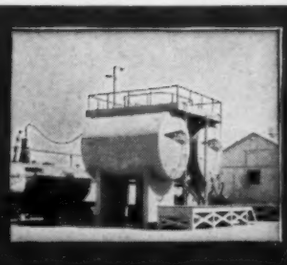

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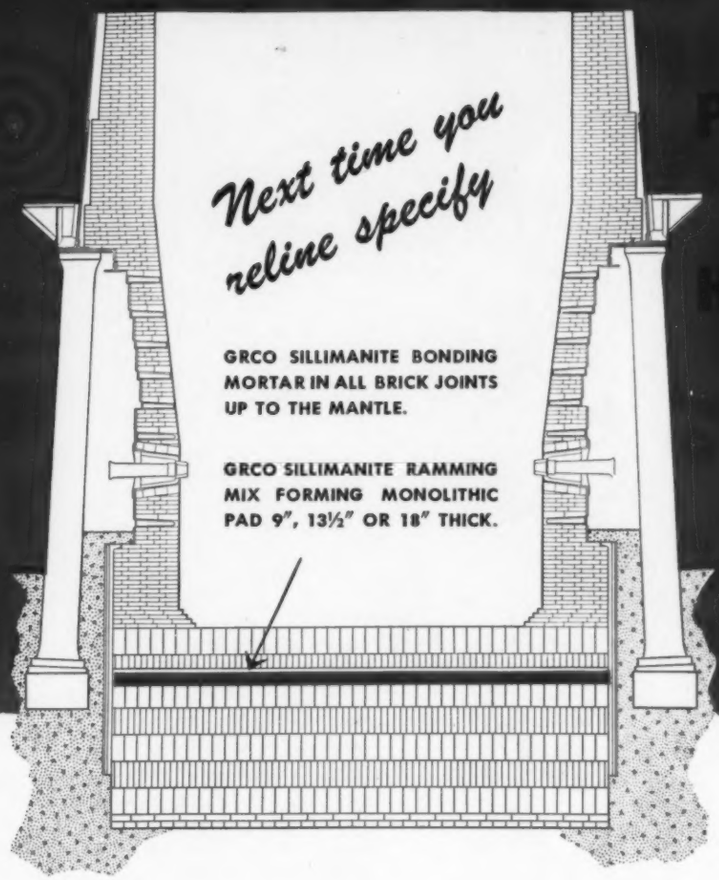
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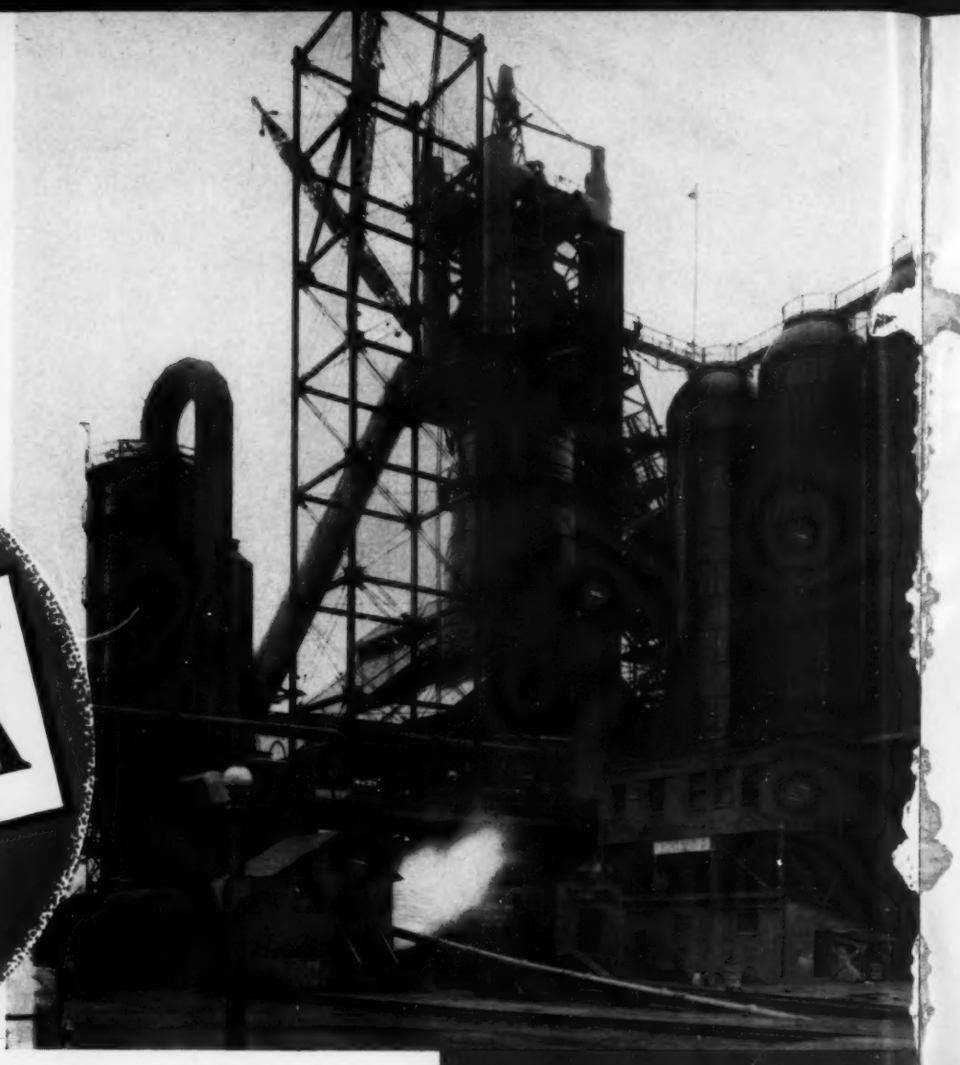

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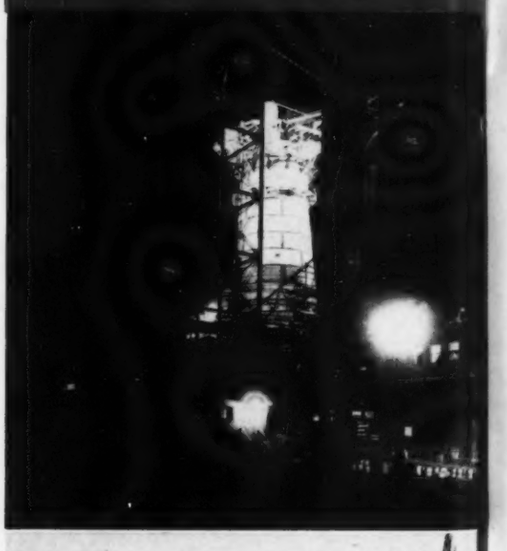

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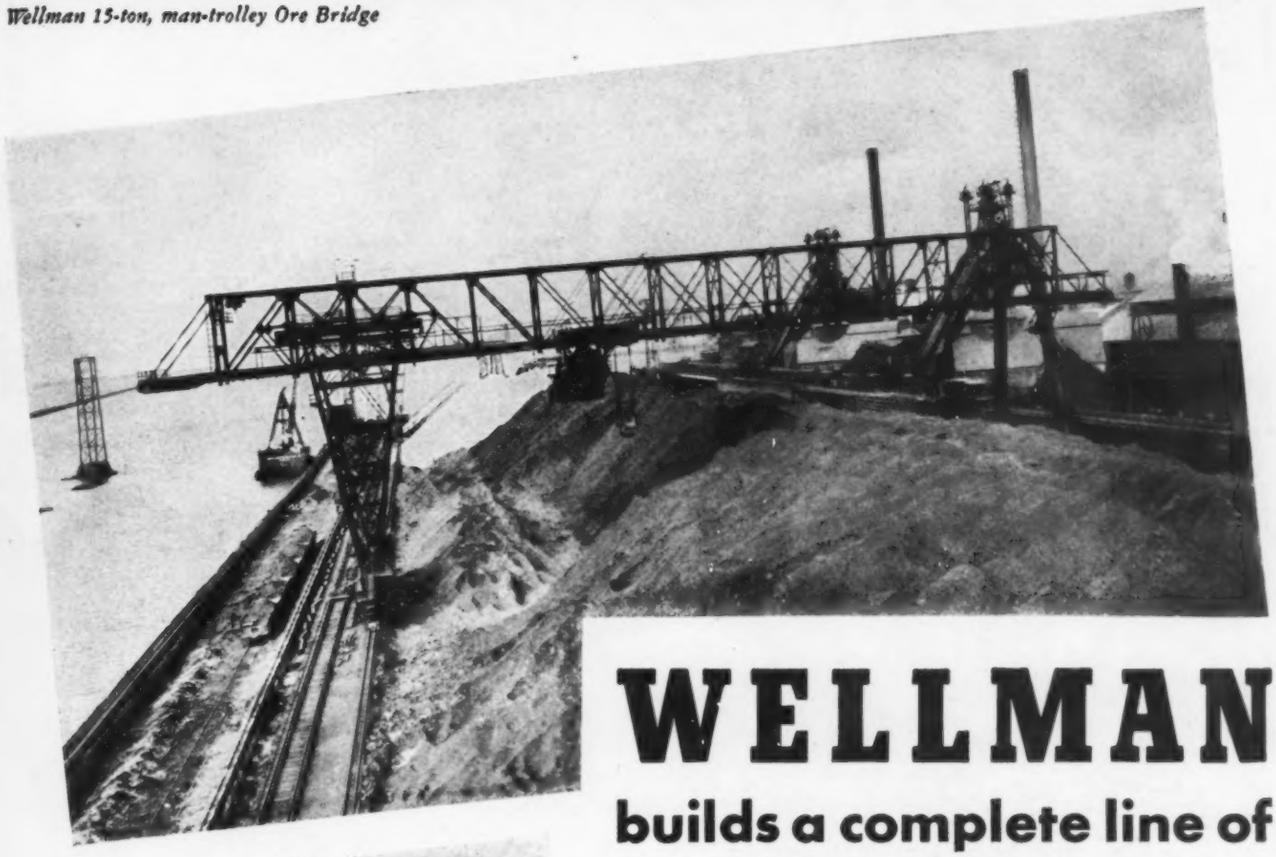

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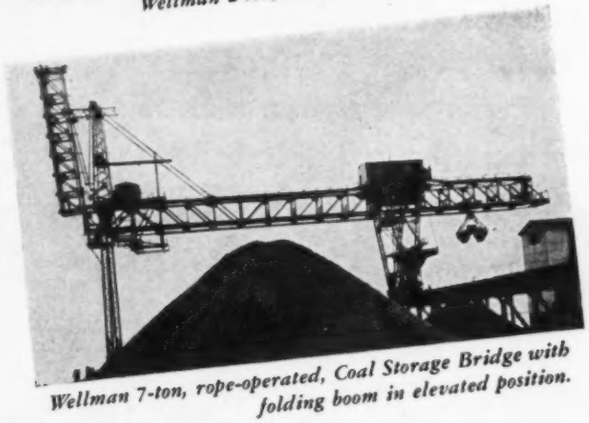

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The Modern Blast Furnace

. . . . this collection of data is another installment in the "Modern" series which the Iron and Steel Engineer has been offering over the past few years . . . . acknowledgment is made of the cooperation of the Blast Furnace and Coke Association of the Chicago District, and of various engineering companies and individuals . . . .

by T. J. Ess

▲ PIG IRON has been made in the United States for nearly 300 years, the first furnace having been located on the Saugus River near Lynn, Massachusetts. Using charcoal and lean bog ores, this furnace produced less than one ton of iron in 24 hours. For 100 years Massachusetts led the colonies in iron production, to be supplanted later by Pennsylvania.

The process today is much the same as in the early days, in that a column of solid iron ores, fuel and flux descends through a vertical shaft, meeting a large volume of ascending hot gases rich in carbon monoxide. The ores are reduced to metallic iron, which melts and is drawn off at intervals from the hearth of the furnace. The non-metallic elements of the ore and coke combine with the fluxing materials to form slag, which is also drawn off periodically.

Though the process has changed but little, the same cannot be said for the furnace. The development of the modern furnace had its origin something over 100 years ago with the abandonment of the small hillside shafts. Development proceeded slowly, however, as evidenced by the Struthers furnace in 1876, which had a 9 ft hearth, a 16 ft bosh, and a height of 55 ft. Using raw coal this furnace produced 67 tons per day.

The development of the past 50 years has been more rapid, and was accomplished through a relatively rapid succession of enlargements and improvements (Figure 1). The furnace of 50-60 years ago had a hearth diameter of about 11 ft, with high, flat boshes. By modern standards, the hearth seems small in proportion to other dimensions. Hearth diameters and furnace heights were increased gradually, and subsequent heights remained more or less stationary while the diameters of all sections of the furnace kept increasing. Table I shows the evolution of several furnaces over the past 50-70 years. Average performance of some of these furnaces is given in Table II.

As the demand for pig iron grew, the number of furnaces increased rapidly, until in 1884 there were 676 blast furnaces in the United States. These furnaces used anthracite or bituminous coal, charcoal or coke, and were of small capacity. These furnaces gave a total capacity of 9,471,182 tons per year, but operated at only about 50 per cent capacity.

As furnace size increased, the number of units declined more or less uniformly (although capacity increased and then held steady) until the recent wartime expansion. Figure 2 shows the number of furnaces existing and in operation for the past quarter-century. It should be noted that the number of units decreased from 436 in 1918 to 249 at the end of 1945 — a drop of 43 per cent in spite of the increase of about 20 per cent in total capacity indicated in Figure 3.

The increase in blast furnace size and individual

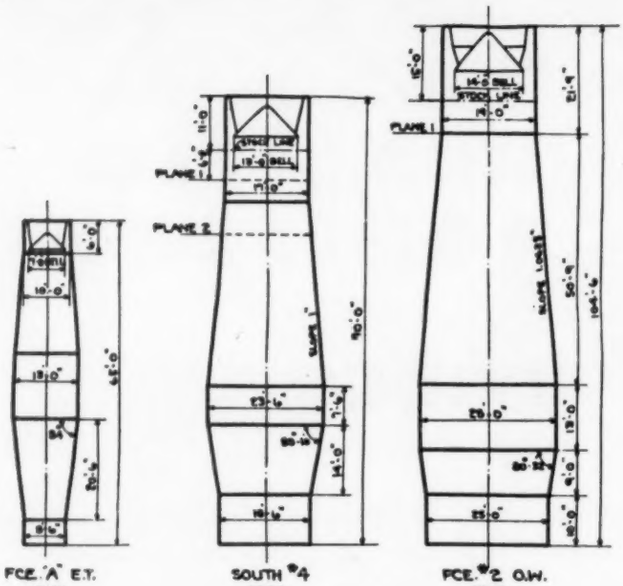
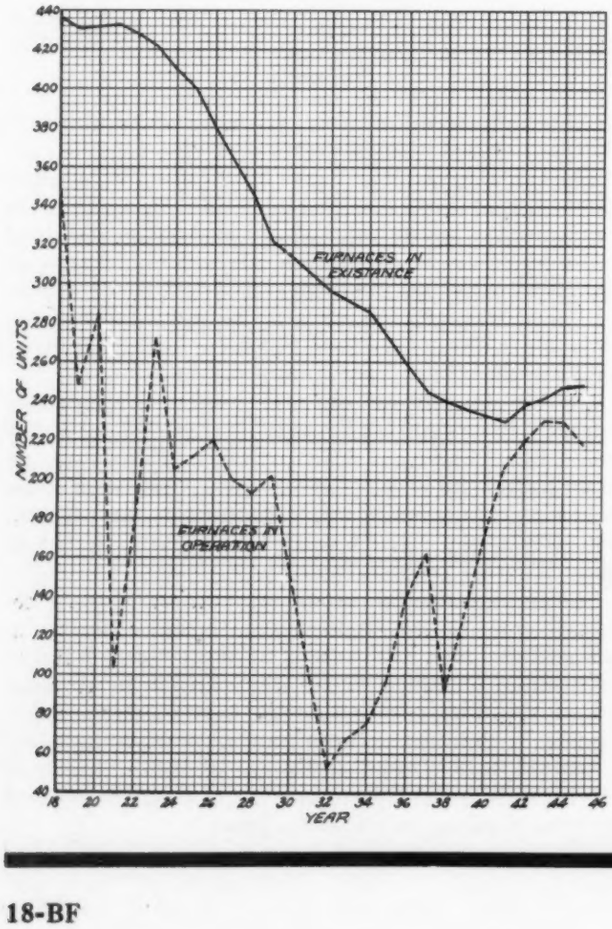


Figure 1 — The lines of these three furnaces show the progress of 50 years during which daily production increased from 100 tons to 1000 tons.

▲

Figure 2 — Chart showing the number of blast furnaces in existence and in operation in the United States since 1918.



capacity is graphically portrayed in Figure 4, which shows the average daily production (net tons per furnace) for each year since 1916. Average production, only 380 tons per day in 1916, doubled in the next 22 years, and in 1944 reached 808 tons per day. The results of the slow-blowing practiced during the depression account for the marked drop in 1931, 1932, 1933 and 1934. The auxiliary lines in the chart furnish an interesting comparison of the practice in various geographical sections.

A complete tabulation of blast furnaces existing in the United States at present is appended to this article. These furnaces fall into sizes as shown in Table III, which also gives comparative figures for 1935 and 1938, indicating the recent trend in furnace size.

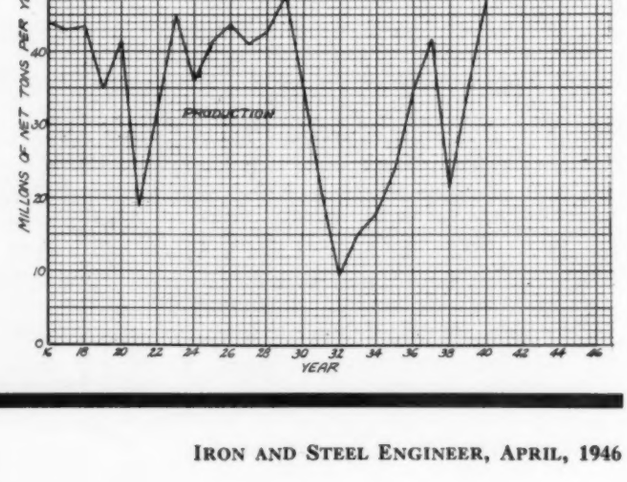
THE PRODUCT

Pig iron is the term applied to iron produced by the reduction of iron ore in the blast furnace. It contains, in addition to iron, 3.50-4.40 per cent carbon, 0.50-5.00 per cent silicon, 0.50-2.00 per cent manganese, 0.035-0.90 per cent phosphorus, and less than 0.05 per cent sulphur.

Carbon occurs in pig iron in two forms, graphitic and combined. The former forms during cooling of the iron and gives the iron a grayish black appearance. It tends to weaken the iron, while combined carbon strengthens it. Rapid cooling tends to increase combined carbon and decrease graphitic carbon. An increase in silicon tends to reduce total carbon, while also decreasing combined carbon and increasing graphitic carbon. The carbon content of pig iron is not controllable in any considerable degree or within close limits.

Silicon in small quantities has little effect on pig iron, but above 4 per cent it imparts brittleness. In iron for basic open hearth use, 1.25 per cent silicon should not be exceeded if excessive erosion of the open hearth is

Figure 3 — Chart showing annual pig iron capacity and blast furnace production year by year since 1916.



to be avoided. For the acid bessemer, a higher silicon content is desirable, as its oxidation produces a large quantity of heat. In castings, one per cent silicon makes it difficult to obtain a chill. Below this percentage, the chilling properties of iron are roughly in inverse ratio to the silicon content. Silicon prevents blowholes and decreases shrinkage in white irons. The amount of silicon reduced in the blast furnace varies with the conditions of the slag and temperature.

Manganese, up to one per cent, strengthens the iron

TABLE I — EVOLUTION OF SEVERAL BLAST FURNACES IN PAST 70 YEARS

Furnace	Blow in	Diameter of hearth, ft-in.	Diameter of bosh, ft-in.	Height of bosh, ft-in.	Angle of bosh	Batter of inwall, in. per ft	Diameter of stockline, ft-in.	Diameter of bell, ft-in.	Height of furnace, ft-in.
Struthers	1871	9-0	16-0	....	.....	....	....	....	55-0
Duquesne	....	14-6	22-0	13-10	74°	0.68	17-0	12-6	100-0
South 5	1881	9-0	21-0	27-3	76°	....	15-0	9-0	75-0
South 5	1884	11-0	20-0	29-6	80°-30′	....	15-4	9-0	75-0
South 7	1908	17-0	22-9	15-1	78°	0.75	17-9	....	94-0
South 4	1914	17-8	22-0	14-6	80°	0.75	17-0	....	90-0
South 4	1926	18-6	23-6	14-0	80°-10′	1.00	17-0	13-0	90-0
E.T.-A	1880	8-6	13-0	20-6	80°	....	10-0	7-0	65-0
E.T.-B	1880	11-0	20-0	27-1	80°	....	17-0	12-0	80-0
E.T.-C	1885	10-0	20-0	20-4	79°	....	16-3	10-6	80-0
E.T.-D	1882	11-6	23-0	30-0	79°	....	17-0	11-0	80-0
E.T.-D	1885	11-0	22-0	29-9	79°	....	15-10	11-6	80-0
E.T.-C	1887	11-0	21-0	20-6	76°	....	15-0	10-3	80-0
E.T.-F	1886	11-0	23-0	22-0	75°	....	16-0	12-0	80-0
E.T.-F	1889	11-0	22-0	22-0	75°	....	15-6	12-0	80-0
E.T.-H	1894	13-0	20-0	15-0	75°	0.481	16-0	....	89-0
E.T.-E	1900	14-0	22-0	14-4	72°-30′	0.809	15-0	....	88-0
E.T.-K	1902	15-6	22-0	13-9	75°	0.75	16-0	....	88-3
O.W. 1	2/14/00	15-0	23-0	15-8	75°-40′	0.535	17-0	12-0	105-0
O.W. 1	7/24/03	16-0	23-0	13-8 7/16	75°-40′	0.433	18-0	11-0	105-0
O.W. 1	5/ 2/05	16-0	23-0	13-8 7/16	75°-40′	0.718	16-6	11-0	105-0
O.W. 1	5/27/08	17-0	23-0	13-8 7/16	77°-37′-9″	0.743	16-6	11-0	105-0
O.W. 1	7/21/11	15-0	23-0	13-8 7/16	77°-37′-9″	0.74	16-6	11-0	105-0
O.W. 1	3/ 9/15	17-6	23-0	13-8 7/16	78°-37′-20″	0.72	16-6	12-0	105-0
O.W. 1	1/ 3/25	19-9	24-6	14-0	80°	0.84	17-6	13-4	105-0
O.W. 1	2/13/37	23-0	26-0	9-0	80°-32′-16″	0.84	19-0	14-0	105-0
O.W. 2	6/ 6/00	15-0	23-0	15-8	75°-40′	0.535	17-0	12-0	105-0
O.W. 2	1/ 5/04	16-0	23-0	13-8 7/16	75°-40′	0.435	18-0	11-0	105-0
O.W. 2	8/19/05	16-0	23-0	13-8 7/16	75°-40′	0.718	16-6	11-0	105-0
O.W. 2	11/28/08	17-0	23-0	13-8 7/16	77°-37′-9″	0.743	16-6	11-0	105-0
O.W. 2	7/22/14	17-0	22-0	12-0	78°-13′-54″	0.634	16-6	12-1	105-0
O.W. 2	11/17/21	18-6	23-6	14-3	80°- 2′	0.83	17-0	13-0	105-6
O.W. 2	5/20/29	25-0	28-0	10-0	80°-30′	1.062	19-0	14-0	104-6
O.W. 3	3/29/01	16-0	23-0	10-9 3/4	72°- 4′	0.635	16-0	12-0	105-0
O.W. 3	9/24/02	16-9	22-0	9-3 1/4	74°-11′	0.325	18-0	12-0	105-0
O.W. 3	5/14/04	16-0	23-0	12-9 7/16	74°-41′- 8″	0.794	18-0	11-0	90-0
O.W. 3	6/21/05	16-6	23-0	14-0	74°-41′- 8″	0.879	16-0	11-0	90-0
O.W. 3	1/27/08	16-6	23-0	14-0	77°- 8′-23″	0.861	17-0	12-0	90-0
O.W. 3	6/29/10	17-0	23-0	14-0	77°-54′-20″	0.835	16-6	12-0	90-0
O.W. 3	12/30/11	17-0	23-0	14-0	77°-54′-20″	0.835	16-6	11-0	90-0
O.W. 3	2/ 5/13	17-0	23-0	14-0	77°-54′-20″	0.835	16-6	12-4	90-0
O.W. 3	1/14/16	17-0	23-0	14-0	77°-54′-20″	0.835	16-6	12-4	90-0
O.W. 3	7/13/19	18-6	23-0	13-6	80°-32′-15″	1.000	16-6	13-0	89-0
O.W. 3	3/13/26	21-6	24-6	9-0	80°-32′-15″	0.800	17-6	13-4	106-6
O.W. 3	6/19/33	23-6	26-6	9-0	80°-32′-15″	0.810	19-6	14-2	106-6

TABLE II — AVERAGE PERFORMANCE OF SOME OLD FURNACES

Furnace	Year started	Hearth diameter, ft-in.	Average of first operating year	
			Gross tons of iron per day	Lb of coke per ton of iron
E.T.-A	1880	8-6	71	2400
E.T.-B	1880	11-0	132	2859
E.T.-D	1882	11-6	180	2570
E.T.-C	1885	10-0	178	2677
E.T.-D	1885	11-0	204	2250
E.T.-C	1887	11-0	198	2230
E.T.-F	1886	11-0	244	2150
E.T.-F	1889	11-0	310	1920

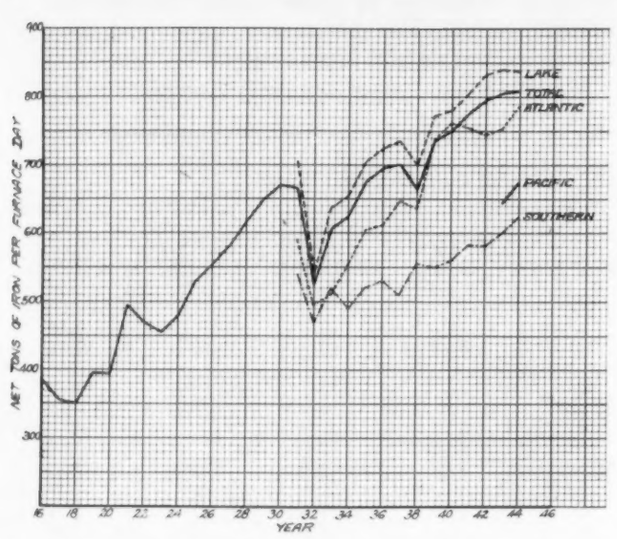


Figure 4 — Chart showing the average daily iron production per furnace-day.

and decreases the bad effects of sulphur. Its presence opposes that of sulphur. In small amounts, it is desirable in basic open hearth practice, where it also aids in the elimination of sulphur. Still smaller contents are desirable in bessemer practice, in order to avoid a "sloppy" heat.

Sulphur is generally supposed to be injurious to iron, and is undesirable in steel or in iron intended for steel making. The best spot in normal steel making operations for the removal of sulphur is the blast furnace, where it is largely slagged off. Its elimination is aided by slag basicity and high temperature.

Phosphorus is the only element entering the blast furnace over which there is absolutely no control. All phosphorus in the raw materials is found in the iron. Its content must be regulated by proper selection of materials. High phosphorus makes pig iron brittle and tends to reduce total carbon content. For castings, phosphorus tends to eliminate blowholes, decreases shrinkage and increases fluidity, but above 0.5 per cent it tends to weaken iron.

From the foregoing, it is apparent that many different analyses of pig iron are required to fulfill the requirements of various consumers. The American Iron and Steel Institute has set up certain standard grades which, for convenient reference, are designated by a prefix letter, a numeral, and sometimes a suffix letter. The prefix letter (see Table IV) denotes grades in order of increasing phosphorus content. Silicon and manganese contents are designated by a six-digit numeral in which the first three figures denote the average silicon content, and the last three figures, the average manganese content. A suffix m indicates a modified manganese range, while s denotes a modified silicon range. For example, B-113175 M denotes basic iron of 1.01-1.25 per cent silicon and 1.51-2.00 per cent manganese, with 0.05 maximum sulphur and 0.40 maximum phosphorus.

It should be noted that the main groups set forth in Table IV do not represent all of the standard analyses but only the main grouping according to phosphorus content. The number of standard analyses in each group is indicated in the column at the right of the table. In general, silicon and manganese are given a 25 point range in each analysis, and also progress in steps of 25 points.

Analyses other than these included in the standard grades may be produced and at times will be required for special purposes. Such analyses are termed non-standard irons.

Uses of the various grades of pig iron are, in general, as follows:

Grade LP is used in making acid open hearth steel and other types requiring an especially low phosphorus content, as well as for special purposes in gray iron foundries, such as the manufacture of rolls, etc.

Grade LPi is used where phosphorus must be low but not as low as set forth in grade A.

Grade Bes is the type generally used as hot metal for the manufacture of steel by the acid bessemer process, and is sometimes used in making acid open hearth steel when its phosphorus content is not objectionable. It is also used in making iron ingot molds and rolls.

Grade M is used mainly for the production of malleable iron castings, and to some extent for gray iron castings where a relatively low phosphorus content is desired.

Grades B and Bs are used in making steel by the basic open hearth process. They are characterized by a low silicon content, with phosphorus higher than is permissible for the acid bessemer.

Grades Fl, Fh and Fs are used, in combination with iron and steel scrap and alloying elements, for producing iron castings in a wide range of types and sizes.

The C grades pertain to charcoal iron, of which very little is produced. In recent years, charcoal iron accounted for only about 0.3 per cent of total iron production.

Grade S is used for the introduction of silicon into steel or cast iron. The term "silvery" comes from the appearance of the fracture, and describes a quality arising from the high silicon content.

Some other ferro alloys (Table V) are also produced in the blast furnace, including ferro-manganese, spiegeleisen, ferro-phosphorus, etc. Almost three-quarters of blast furnace production, however, is in the basic grades, with 15 per cent bessemer, 4 per cent foundry, 4 per cent malleable, 3 per cent ferro-alloys and 1 per cent low phosphorus and miscellaneous forming the remainder.

Figure 3 shows total blast furnace production in the United States since World War I, as well as the total

TABLE III — SIZE GROUPING OF BLAST FURNACES

Hearth diameter, ft	1935	1938	1945
15 and less	53	31	25
15 - 20	128	115	99
20 - 25	74	81	86
25 - 26	3	6	23
26 - 27	2	2	10
27 - 28	....	....	4
28 - 6	1	2	2
	261	237	249

blast furnace capacity of the country. It will be noted that annual capacity increased from about 50,000,000 net tons in 1916 to about 70,400,000 tons in 1945, which capacity includes a number of furnaces substantially completed during the war but never actually put in operation.

RAW MATERIALS

Raw materials used in blast furnace operation are iron ore, flux, fuel and air. Average consumption of materials per ton of pig iron is given in Table VI.

Iron Ore

Iron ores are made up of two parts, the iron bearing minerals consisting of definite compounds of iron, and the gangue or other substances mixed with these compounds. In the United States, the iron ores used are

TABLE IV — A.I.S.I. STANDARD GRADES OF PIG IRON

Designation	Per cent				No. of standard analyses in main group
	Si	S max	P	Mn	
LP — Low phosphorus	0.50-3.00	0.035	0.035 max	0.75-1.25	26
LPi — Intermediate low phosphorus	1.00-3.00	0.05	0.036-0.075	0.75-1.25	24
Bes — Bessemer	1.00-3.00	0.05	0.076-0.100	1.00-1.25	16
M — Malleable	0.75-3.50	0.05	0.101-0.300	0.50-1.25	33
B — Basic (Northern)	1.00 max-1.50	0.05	0.400 max	1.01-2.00	6
Fl — Foundry (Northern, low phosphorus)	1.75-3.50	0.05	0.300-0.500	0.50-1.25	24
Fh — Foundry (Northern, high phosphorus)	1.75-3.50	0.05	0.501-0.700	0.50-1.25	24
Fs — Foundry (Southern)	1.75-3.50	0.05	0.700-0.900	0.40-0.75	8
Bs — Basic (Southern)	1.00 max-1.50	0.05	0.70-0.90	0.40-0.75	3
Cn — Charcoal (Northern)	0-2.88 min	0.025	0.100-0.200	0.15-1.00	53
Cl — Charcoal (Southern)	0.50-3.00	0.035	0.035 max	0.40-1.00	30
C2 — Charcoal (Southern)	0.50-3.00	0.035	0.100-0.200	0.40-1.00	30
C3 — Charcoal (Southern)	0.50-3.00	0.035	0.400-0.700	0.40-1.00	30
S — Silvery	5.00-17.00	0.05	0.300 max	1.00 max-2.00	72

Carbon content is not usually specified, as it is not readily controlled.
Each of the above grades includes a number of standard analyses, indicated in the right-hand column. In general, in these variations silicon and manganese change in steps of 25 points (0.25 per cent). A range of 0.25 per cent is usually allowed for these elements in each analysis.

TABLE V — TYPICAL ANALYSES OF FERRO-ALLOYS FROM BLAST FURNACE

	Si	S max	P max	Mn	C
Ferromanganese	1.25 max-7.00	0.05	0.10-0.35	78.0-85.0	Up to 7.50
Ferrophosphorus	1.5 -1.75	0.05	17.0-25.0	0.07-0.50	1.10-2.0
Spiegeleisen	1.00 max-4.50	0.05	0.25	16.0-28.0	6.50 max.
Ferrosilicon	8.0 -18.0	0.04-0.06	0.05-0.15	.....	0.15-1.50

TABLE VI — CONSUMPTION OF RAW MATERIALS

Year	Net tons per net ton of pig iron (excluding ferro-alloys)					
	Iron ore	Scrap	Mill cinder, scale, etc.	Total	Limestone	Coke
1944	1.725	0.045	0.122	1.892	0.389	0.905
1943	1.745	0.044	0.114	1.903	0.387	0.900
1942	1.754	0.034	0.124	1.912	0.387	0.896
1941	1.717	0.038	0.140	1.895	0.362	0.873
1940	1.729	0.029	0.134	1.892	0.362	0.878
1939	1.711	0.038	0.148	1.897	0.355	0.880
1938	1.731	0.035	0.145	1.911	0.347	0.887
1937	1.718	0.041	0.138	1.897	0.361	0.903
1936	1.701	0.044	0.144	1.889	0.362	0.895
1935	1.693	0.044	0.161	1.898	0.362	0.871
1934	1.662	0.219		1.881	0.359	0.881
1933	1.660	0.217		1.877	0.351	0.864
1932	1.496	0.256		1.752	0.345	0.872
1931	1.652	0.210		1.862	0.346	0.884

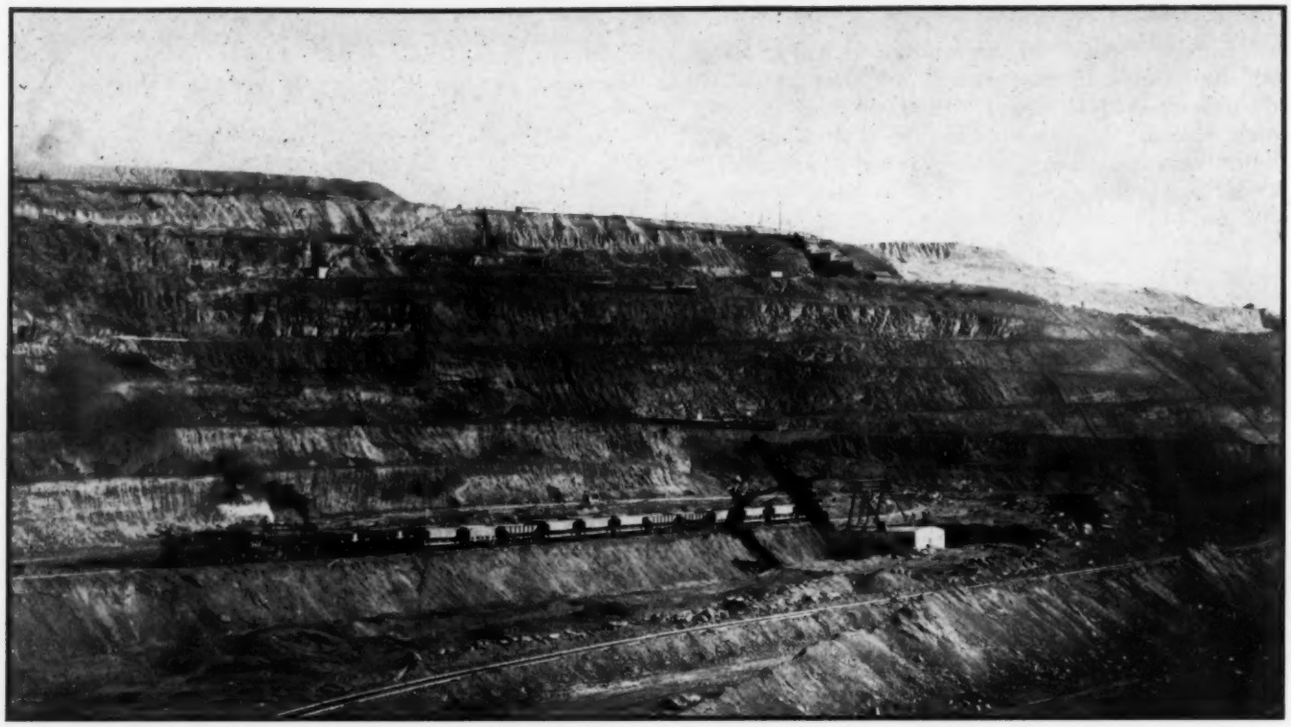


Figure 5 — The Hull-Rust iron ore mine at Hibbing, Minnesota, is an example of the large open pit mines in the Mesabi range.

almost exclusively oxides, which fall into the following classifications:

Magnetite — Found in Arkansas, Pennsylvania, New Jersey and New York. Gray to black in color. Specific gravity, 4.9-5.2. Iron in Fe_3O_4 (72.4 per cent Fe, 27.6 per cent O_2).

Hematite — Widely distributed in a variety of mineralogical forms. Found in Michigan, Minnesota, Wisconsin, Alabama, Missouri, Utah, Colorado, California. Red to blue in color. Specific gravity, 4.9-5.3. Iron in Fe_2O_3 (70 per cent, Fe, 30 per cent O_2). Most of the world's ores fall into this classification.

Brown Ores — Hydrous ferric oxides, widely distributed. Brown in color. Specific gravity 3.6-4.0. Limonite is a principal type of brown ore, and contains iron in the form $2\ Fe_2O_3 \cdot 3\ H_2O$ (52.31-66.31 per cent Fe).

Principal ore deposits of the United States are as follows:

Marquette Range, in the north peninsula Michigan, was the first of the lake deposits, being opened in 1844. It consists mainly of soft red hematites, with some magnetites, limonites and hard hematites. This range has been producing principally low-phosphorus non-bessemer ore, with some siliceous and manganiferous.

Menominee Range, several miles south of the Marquette range, lies in Michigan and Wisconsin and was opened in 1877. It is principally hematite, and mainly produces high-phosphorus non-bessemer ore, with some low-phosphorus.

Gogebic Range, west of Marquette range, is located in Michigan and Wisconsin. It was opened in 1884, and consists mainly of soft, red, partially dehydrated hematite. Ores are principally low-phosphorus, non-bessemer ores, with some bessemer and manganiferous grades.

Vermillion Range, located in Minnesota, was opened in 1884, and is made up of hard red and blue hematite, principally low phosphorus, with some bessemer ore.

Mesaba Range, opened in 1892, is located in Minnesota. It is made up principally of soft hydrated hematite and limonite, which varies from very fine to fairly coarse, hard granular ore. In recent years, this range has produced about 75 per cent of the total production of Lake ores. Production falls principally in low-phosphorus and bessemer grades.

Cuyuna Range, in Minnesota, was opened in 1911. It contains some very high manganese ores, and is principally a source of manganiferous ores, with some high-phosphorus non-bessemer ore.

Red Mountain, in Alabama, contains a variety of red hematites in a thick bed about 62 miles long. Although from the same vein, these hard red ores differ appreciably in various mines. There is a distinct trend of increased iron and silica, and decreased lime from the west end to the east end of this deposit. Also, ore from the east end of the vein is very difficult to reduce in the furnace.

The *Adirondack region* of New York, the *Wharton district* of New Jersey and the *Cornwall district* of Pennsylvania produce magnetites, which are generally crushed and prepared by magnetic concentration and sintering before use in the blast furnace.

Utah ore deposits support the greater part of iron production in the western states. They are mainly hard hematites containing a varying percentage of magnetite.

California deposits vary widely, the most used deposit being a relatively hard mixture of hematite and magnetite with small amounts of pyrites.

Some ores are imported for use in plants along the Atlantic coast, principally from Chile, Cuba, Norway

Figure 6 — This ore carrier established a world's record haul of 18,543 tons of iron ore in one trip down the Great Lakes. This view shows the unloading operation at the Conneaut, Ohio, harbor dock.

and Sweden. In normal times, imports make up about 3½ per cent of total consumption.

Iron ore is mined by both open pit and underground methods. Most of the mining in the giant Mesabi range is open pit, while almost all of the old ranges, (Marquette, Menominee, Gogebic and Vermillion) employ underground methods. For all lake ores, 57 per cent is open pit direct, 24 per cent is underground direct, and 18 per cent is concentrated. In Alabama, Red Mountain operations first began with open cuts along the outcroppings, but are now completely underground.

Lake ores supply furnaces in western New York, western Pennsylvania, Ohio, Illinois, Indiana, Michigan, Minnesota and Wisconsin, and normally form 80-85 per cent of the total production in the United States. Alabama ore accounts for approximately 8 per cent of the total, with the eastern magnetites making up 3-5 per cent. The remainder is made up principally from western states.

During the recent peaks of wartime production, iron ore consumption exceeded 100,000,000 tons per year, hitting a peak of 118,000,000 net tons in 1942.

The high grade ores of the United States are being rapidly depleted, and according to present estimates of ore reserves, the industry will be faced with the necessity of using lower grade ores.

In physical condition, iron ores vary from soft clay-like or earthy masses to hard compact masses. Both extremes are apt to give trouble in the blast furnace. Soft ores choke up the furnace and produce a large

TABLE VII — ANALYSES OF IRON ORES

	Per cent							
	Iron (natural)	Phosphorus	Silica	Manganese	Al_2O_3	CaO	MgO	Moisture
Marquette	37-55	0.04-0.85	4-43	0.21-4.00	.....	.....	.....	3-15
Menominee	38-53	0.02-0.42	6-43	0.1 -10.0	2-3	0.1 -0.2	0.5 -0.6	1.4-8.9
Gogebic	51-54	0.04-0.08	7-8	0.4 -2.6	.....	.....	.....	10-12
Vermillion	41-57	0.04-0.09	7.5 -19.9	0.08-1.0	.....	.....	.....	4.9-9.6
Mesaba	37-54	0.04-0.09	7.8 -38.0	0.11-5.72	1-2	0.15-0.25	0.13-0.20	6-12
Cuyuna	41-49	0.10-0.26	8.5 -12.7	0.6 -6.5	2-3	0.62	0.15-0.20	9-14
Alabama (red)	32-37	0.3 -0.4	11-24	0.16	3-4	10-20	1	1.0
Alabama (brown)	47-50	0.2 -0.7	7-11	0.5 -0.7	.....	.....	.....	7-13
Eastern magnetites (sintered concentrates)	58-68	0.01-0.04	3-8	0.03-0.12	1-3	0.3 -3.0	0.1 -3.5	.....
Colorado	48.9	0.07	9.3	1.5	0.6	3.8	0.9	.....
California	51-55	0.1	5-6	0.1	1	4-6	3-4	.....
Utah	52-56	0.2	7-9	0.1 -0.2	1-3	2-4	2	3-5
Newfoundland	51.4	0.89	11.9	0.11	3.8	3.0	0.6	1.50
Cub	53.5	0.015	4.0	0.85	13.0	.....	.....	2.50
Chile	57.8	0.037	8.6	0.11	1.6	1.8	2.5	.....

amount of flue dust. Hard ores and large lumps are hard to reduce and require more fuel. A high percentage of fines cuts furnace production.

Impurities which accompany the iron oxide in the ore may be grouped under three heads:

1. Impurities not reduced in the blast furnace include Al_2O_3, CaO, MgO, Na_2O and K_2O. These are not particularly objectionable in reasonable quantities. Lime and magnesia act as flux. Alumina up to about 5 per cent is useful in regulating furnace operation. The alkalies are usually driven off in the gas as dust.
2. Impurities partially reduced in the furnace include silica, silicates, sulphates, and manganese compounds. Silica and silicates form a large part of the gangue and require an equal weight of lime or magnesia to flux them. Silica can be controlled to a considerable extent in the furnace. Sulphur, however, must be watched, as slag cannot absorb much more than 3 per cent sulphur. Approximately 75 per cent of the manganese in the ore enters the iron. Manganese up to 2 per cent in the ore is satisfactory for ordinary use. Ore containing 2-10 per cent must be mixed with low manganese ores. Ores with 15 per cent or more manganese are generally used for the production of spiegel.
3. Impurities completely reduced in the furnace include phosphorus, which is carried on into the iron. For bessemer iron, phosphorus must be low; the per cent phosphorus in the ore +0.015 should be less than one-thousandth of the iron content in per cent of the ore.

Water adds to the weight of ore and raises transportation costs. Lake ores contain an average of about 11 per cent moisture, ranging from 0.4 per cent in some hard red hematites up to 17.0 per cent in a few soft red ores.

Iron ores are graded into five principal commercial groups:

Bessemer — Phosphorus 0.045 per cent or less.

Low-phosphorus — Phosphorus low enough to make 0.035 per cent phorphorus in iron.

High-phosphorus — Over 0.18 per cent phosphorus.

Manganiferous — Over 2.0 per cent manganese.

Siliceous — 18.0-20.0 per cent or more silica.

Analyses of lake ores in 1944 showed these groups to average as shown in Table VIII.

Grading is based on car analyses, which determine the groups into which the cars are placed. Cars are then mixed so as to give iron, silica, phosphorus and manganese contents as required in a given shipment.

It has been found advantageous in many cases, particularly since the quality of ores has shown deterioration, to put ore through some form of benefication. Such processes, which vary according to the nature of the ore, may include one or more of the following operations:

Crushing to break up big lumps.

Screening to separate ore into size groups.

Washing to remove clay, sand, etc.

Drying to remove moisture.

Magnetic concentration, through which magnetic ores may be separated from some non-magnetic impurities.

Roasting to eliminate some objectionable ingredient or to make the ore magnetic.

Nodulizing to agglomerate fine ore and flue dust.

Sintering to agglomerate fine ore and flue dust.

Although all of these operations are used to a greater or less degree at the ore mines, screening and sintering are the only operations used to any great extent at the blast furnace plants.

The effects of size of ore charged into the furnace have been summarized as follows:

Figure 7 — Raw materials are stored in a bedding system, being piled by traveling stockers as shown in the foreground and withdrawn by reclaimers as shown at the left.

TABLE VIII — AVERAGE ANALYSES OF LAKE ORES, 1944

	Per cent					Per cent of total shipments
	Iron	Phosphorus	Silica	Manganese	Moisture	
Bessemer	54.18	0.038	8.63	0.35	9.43	21.0
Low-phosphorus (non-bessemer)	51.56	0.071	8.04	0.66	11.03	69.4
High-phosphorus (non-bessemer)	51.37	0.429	7.25	0.30	9.48	5.6
Manganiferous	43.21	0.208	9.93	5.70	11.67	3.3
Siliceous	37.10	0.041	42.72	0.01	2.85	0.7
Combined grades	51.72	0.088	8.42	0.74	11.02	100.0

1. Operation with various sizes of ore charged alternately results in decreased coke consumption and increased iron production when compared with operation with one size only.
2. Observations indicate that a decrease in the over-all size of the ore used tends to improve production, as does feeding a charge containing coarse ore followed by a charge containing fine ore, termed layer filling.
3. Furnace operating results indicate that a greater burden could be carried with than without layer filling due to better gas-solid contact obtained by altering the sizes of ore charged.
4. The carbon monoxide to carbon dioxide ratio in top gas decreases with more ore sizes, indicating better fuel economy with each change in ore size.

Several tests have shown that the use of sinter to the extent of 40 per cent of the metallic charge increases iron production 10-19 per cent, and decreases coke consumption about 15 per cent, flux consumption about 20 per cent, and flue dust production as much as 50 per cent, although these results have not been universally accepted.

Where the analysis of ore entering the plant varies from day to day, some form of blending is desirable. Several recent installations take incoming ore through crushing and screening equipment, and then convey it to bedding piles where it is piled by traveling stockers to average out variations in analysis. A reclaimer, through an inclined oscillating rake attachment, takes off an accurate cross-section of the pile, and the ore is then perhaps rescreened and conveyed to the blast furnace stock bins.

Instead of bedding piles, some use is made of bins or silos in which ore is separated according to chemical analysis, and perhaps according to size. The feed from each bin may be so controlled as to give any desired mixture to the furnace, while size segregation may also be obtained.

In northern plants, where the year's ore supply is stocked during the lake navigation season, bedding as described above is not practiced. Rather, ores are graded and blended at the mines, in classifying yards and in the ore carrier to give the desired mixture. Then, when received at the furnace plant, the ore is unloaded into a storage yard, where the different analyses or types are segregated into separate piles.

If ore comes to the plant by water, it is unloaded by unloaders or by unloading-stocking bridges. If received by rail, ore cars are dumped into the ore yard by a car-dumper or through a system of trestle tracks.

The ore yard is generally about 300 ft wide and of such a length as to accommodate the ore, limestone and perhaps the coking coal that is required to carry the plant through the period during which incoming shipments are stopped by seasonal conditions.

The ore yard is served by an ore bridge, or several if the number of furnaces requires, which, with the aid of an ore transfer car running along the high line, transfers ore from the chosen pile in the yard into the desired stock bin.

Flux

Flux in the blast furnace charge serves two major purposes. It renders impurities in the other materials of the charge more fusible and hence aids in their separation from the metallic content of the charge. It also provides a substance with which other impurities may combine rather than passing into the metal.

Limestone is the flux used in blast furnace operation, and is widely distributed over the United States. In some respects, its composition varies widely:

	Per cent
Lime, CaO	30-54
Magnesia, MgO	0.6-22.0
Silica, SiO_2	0.6-4.5
Alumina, Al_2O_3	0.4-3.0
Phosphorus, P	0.001-0.025
Sulphur, S	0.004-0.132

The lime and magnesia are actually in the form of carbonates, but their CO_2 (44.0 per cent in lime, 52.2 per cent in magnesia) is seldom reported in analyses.

Stones running to the low side of the lime range and to the high side of the magnesia range are dolomitic, and are considered by some furnace operators to be inferior to the calcite stones with their high lime and low magnesia contents, although dolomitic stones are practically the only fluxes used along the eastern seaboard. Most of the stones used in the United States range 50-54 per cent CaO and 0.6-4.0 per cent MgO. Low phosphorus, 0.006 per cent or less, is preferable in making bessemer iron. Low silica, under 1.5 per cent, is desirable in basic iron production but the phosphorus may be somewhat higher than for bessemer iron.

Inasmuch as the silica and alumina in the stone require basic materials to flux, the actual value of a flux depends on its "available base," which equals $(CaO + MgO) - (SiO_2 + Al_2O_3)$.

Stone should be free of clay, and preferably crushed, washed and screened. Sizes are mainly a matter of operator's preference, some asking for ½ in. x 5 in., some for 1½ in. x 4 in., and some 2 in. x 3 in.

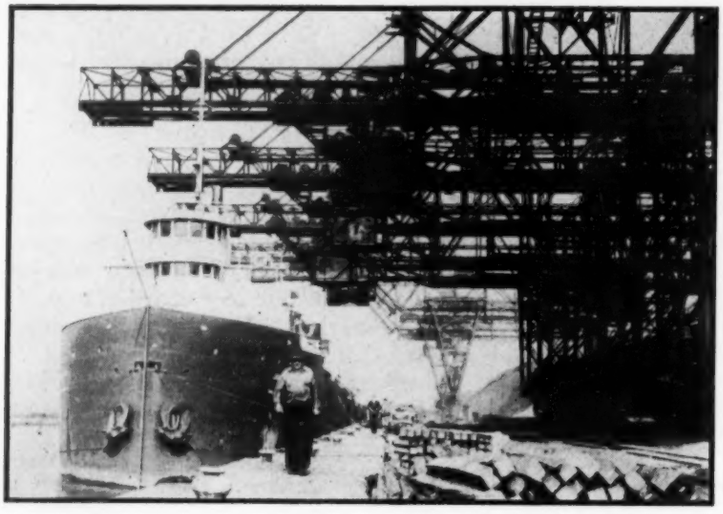


Figure 8 — The combination of unloaders and bridges is widely used at blast furnace plants located along the Great Lakes.

Figure 9 — Some lakeside plants employ only unloading-stocking bridges, as illustrated by these 15 ton units.

Fuel

Blast furnace fuel shows a history of four principal (and overlapping) periods: charcoal (1645-1855), anthracite coal (1855-1875), beehive coke (1875-1919), and by-product coke. Raw bituminous coal was also used between 1860 and 1890 but exact records are unavailable. By-product coke is now almost universal, although there are two charcoal-burning furnaces still in existence and the recent peaks of wartime production recalled many beehive coke ovens into service.

Coke analysis naturally depends on the analysis of the coal from which it is made. All fixed carbon and ash in the coal remains in the coke; volatile matter in the coal is to a large extent driven off, although a slight amount is usually found in the coke. About 80 per cent of the sulphur in the coal carries on into the coke. In general, analyses of coke will fall within the following range:

	Per cent
Fixed carbon	85-89
Volatile matter	0.9-1.6
Sulphur	0.7-1.3
Ash	5.5-13.0
Moisture	3.0-8.0

Coke for use in the blast furnace should be fast-burning, not friable, and not too soft. Fast-burning coke is essential for high rates of furnace driving. Friable coke results in excessive breakage in handling, and with other conditions equal, sofe coke increases solution loss in the furnace. It is generally thought that coke slightly on the green side — 1.0-2.0 per cent volatile, but no spongy edges — is advantageous in the blast furnace, although some operators prefer a hard burned coke.

Some plants run daily tests on coke to check its porosity, combustibility, shatter index, etc., while others merely specify a certain screen size and an absence of breeze. In order to keep performance figures comparable, coke weights are usually adjusted to some standard moisture figure — say 3 per cent.

Miscellaneous Materials

Other materials, principally by-products of other steel plant operations, are also charged into the blast furnace in order to recover metallics or for their flux value. These include:

Roll scale — This is almost pure iron oxide, and contains 67-70 per cent iron and perhaps 4-5 per cent silica.

Mill cinder — Principally from heating furnaces. Contains approximately 53 per cent iron and 24 per cent silica.

Slag — Principally from basic open hearth furnaces. Analyses approximately:

	Per cent
Fe	10-16
Mn	4-7
CaO	43-48
MgO	6-8
SiO_2	10-20
Al_2O_3	2-8
S	0.16-0.22
P	1.50-2.35

Scrap — Miscellaneous metallics, such as ladle kish, bessemer spittings, borings, turnings, etc.

THE FURNACE STACK

Old furnaces were generally supported upon wooden piles, which are economical when the loads to be carried will permit design of a pier with a footing of reasonable size. Wooden piles also deteriorate due to the effects of heat transmitted through the concrete and of fluctuation in ground water level.

The heavy loading entailed by the modern blast furnace, which concentrates a load of 16,000-17,000 tons

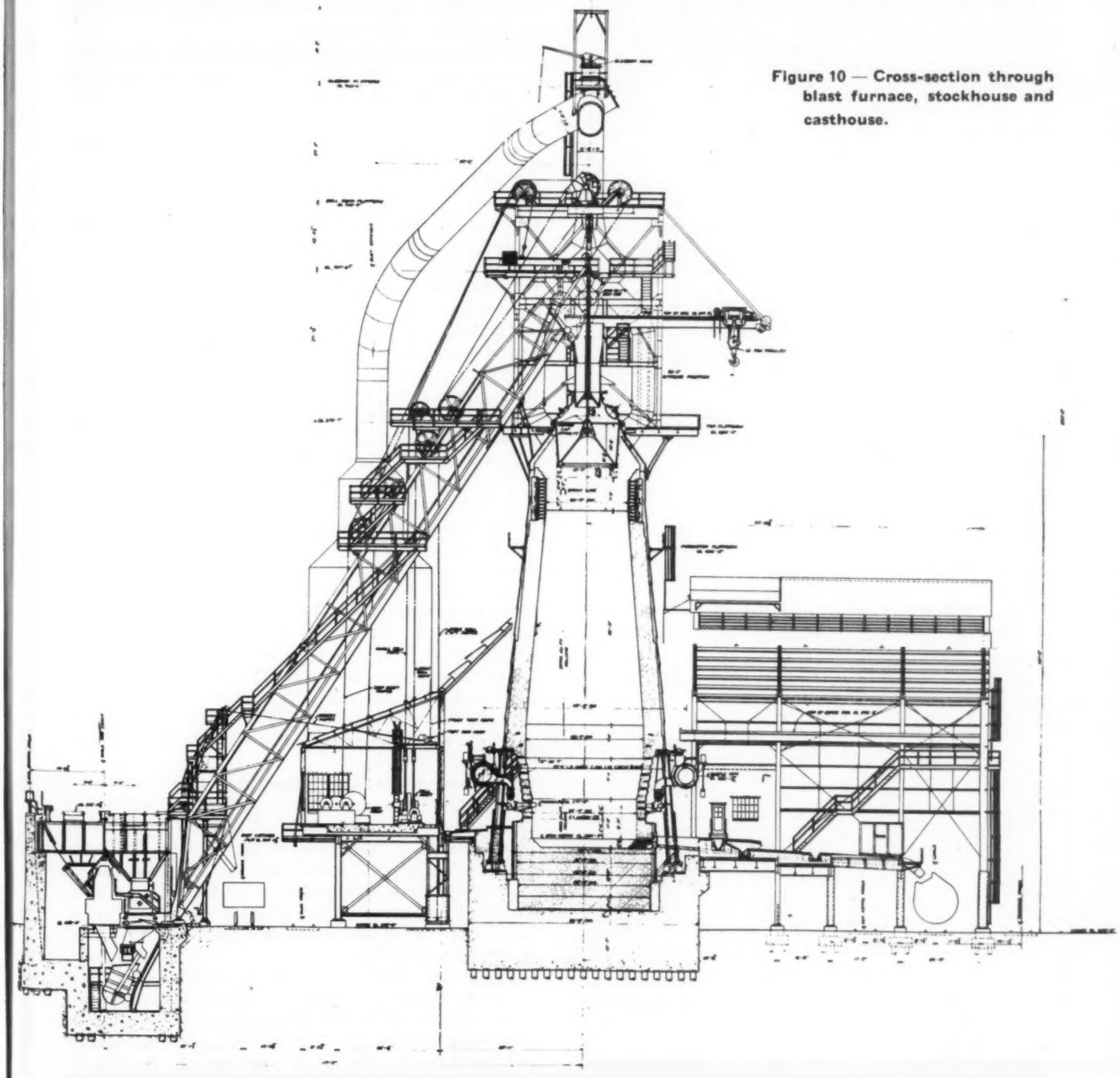


Figure 10 — Cross-section through blast furnace, stockhouse and casthouse.

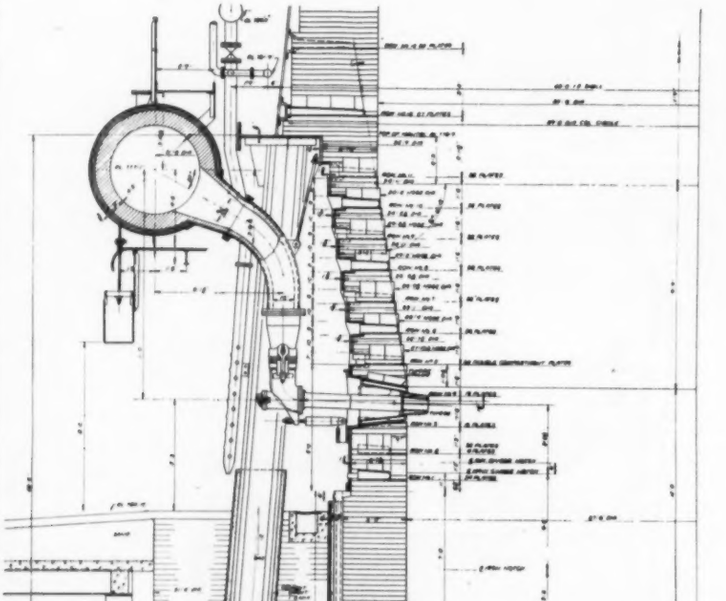
in a space about 70 ft square, is too much for wood, and concrete piling is preferable.

Several recently constructed furnaces are each supported on 185 piles of 16 in. pipes driven open-end to bedrock, blown out with compressed air, and filled with concrete. Another plant used step-taper piles 70-75 ft long, consisting of 10 in. pipe surmounted by a sheet steel section of about one-half of the total length, all filled with concrete. These piles were spaced on 36 in. centers in both directions. Each pile has a total carrying capacity of as much as 100 tons, although conventional loading may only be half of that. A blast furnace, with its stoves, cast house, stock house, dust catchers, etc., may require 1200-1500 piles.

Topping off the supporting piles is the furnace slab of reinforced concrete, 40-60 ft in diameter and in some cases as much as 15 ft thick. The refractory furnace bottom, 13-17 ft. thick, rests on the concrete slab.

The hearth requires heavy, strong construction. It is usually encased in a solid jacket made of welded or riveted steel plate about 1½ in. thick and perhaps 14 or 16 ft deep from the cinder notch level. Cast steel jackets may also be used. In this design a number of water cooled segments 5 or 6 in. thick are assembled in the shape of a truncated cone. These segments are bolted together. In addition, they are also held by a number of 12 in. x 1½ in. steel bands, tightened by wedges. This construction is more expensive than the cast iron stave construction.

Figure 11 — Drawing showing details of hearth and bosh construction.



The hearth jacket may be exposed or it may be embedded in concrete. The former is cheaper and at the same time accessible. Water-cooled cast iron plates or staves between this jacket and the enclosed brickwork provide cooling. A reinforcing plate is usually provided at the iron and cinder notches.

The iron notch opening in the hearth jacket is usually strengthened both inside and outside with reinforcing plates about one inch thick. A hood around this opening projects about one foot beyond the jacket to receive the end of the casting runner.

The opening left in the brickwork for the iron notch is approximately 9 in. wide x 12 in. high. This opening is usually formed by special shapes with its top surface horizontal and its bottom sloped down toward the inside of the furnace to suit the maximum drilling angle. In starting up a furnace, a 6 or 8 in. steel pipe is usually put into this opening and mudded solidly in place. The pipe is later pulled out, and the hole left is plugged by the mud gun. The clay burns hard for the entire length of the hole — 3 to 5 ft. The hole may be opened by an electric rotary drill which makes a 3 in. hole which is then finished by sledging a tapping bar or by a ⅛ in. oxygen lance.

Automatic mud guns, usually electrically driven, are almost universally applied to modern furnaces, so that the iron notch may be plugged after casting without taking the wind off of the furnace.

The cinder notch is a tapering circular opening through the lining of the furnace hearth. It is usually placed about 45 degrees away from the iron notch. A water-cooled cast iron or bronze cinder notch cooler is built tightly into this opening. A bronze water-cooled intermediate cooler slips inside of the notch cooler and the bronze monkey in turn slips inside of the intermediate cooler. In operation, this hole is kept closed by an iron plug on a long handle, usually mechanically operated through levers. A second cinder notch is sometimes built into the furnace to be used only in case of emergency.

The tuyeres which circle the furnace near the top of the hearth may be supported by a tuyere jacket fabricated of steel plate about 1½ in. thick and 5 or 6 ft wide. Tuyere cooler holders are welded in the jacket at the proper places.

The bosh section of the furnace is generally of banded construction, although a steel plate bosh jacket has also been used to some extent. The bosh section does not support any other part of the furnace structure, but is itself supported from below by the hearth jacket, or, where a steel plate jacket is used, suspended from the mantle ring at the top of the bosh section. Bosh bands may be 4-7 in number, and fabricated of 1½ in. plate 12-24 in. wide.

The mantle ring is supported by columns which rest upon the furnace foundation. Fabricated structural steel columns are now in general use, composed of a large beam section (12-16 in.) with heavy cover plates and cast iron guards. In determining the number of

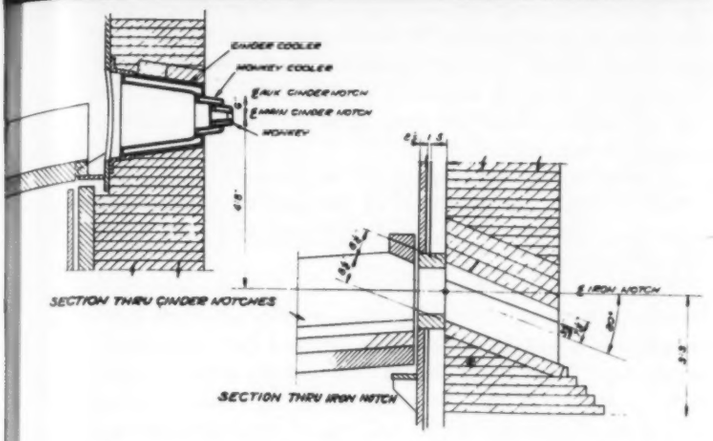
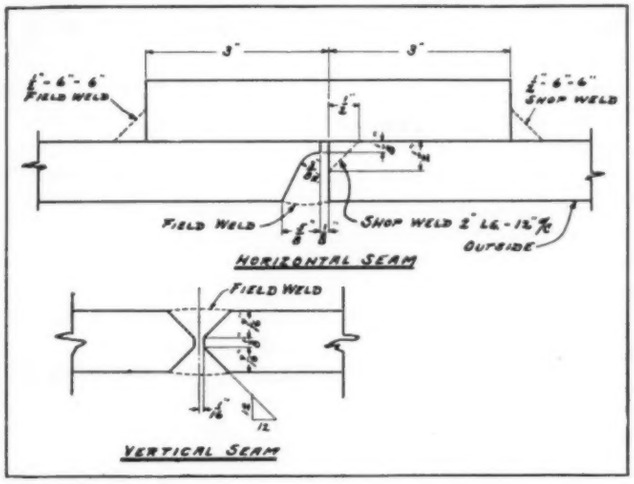


Figure 12 — Sketch of details of iron notch and cinder notch.

▲

Figure 13 — Sketch showing details of seams for welded blast furnace stack.



columns to be used, it is necessary to consider the number of tuyeres to be used in the furnace as well as its structural stability. Eight to twelve columns are desirable for stability, but they must be so placed as not to be in line with any of the tuyeres evenly spaced around the hearth.

Above the mantle ring, and resting upon it, is the furnace shell, constructed of steel plate ¾-1¼ in. thick. Some shells use 1, 1⅛ or 1¼ in. plate throughout, while others use these thicknesses for a few rings above the mantle, then drop to ¾ in. or even ⅝ in. thickness up toward the top, where they again get heavier.

Either riveted or welded construction is used. In the former construction, both horizontal and vertical joints are double riveted. In one welded furnace which has operated successfully for a number of years, the vertical seams were of the standard double-V design. At the horizontal joints, the top of each plate was square, with ⅜ in., 45 degree notches cut at intervals on its inner face (Figure 13). A butt strap, 1 in. x 6 in. was welded to the inner face of the plate at each notch, the welds being made in the notch and at the bottom of the strap. About 3 in. of the length of the butt strap was left projecting above the top edge of the plate, acting as a guide to hold the next plate above. The bottom of each plate was shaped to form a modified U butt weld. One inch plate was used throughout.

It is felt that the residual stresses left in the welded shell are probably no greater than those set up in riveted construction by drifting to shape. In either riveted or welded construction, it is desirable to keep the number of joints at a minimum.

Since tuyeres are spaced between the columns which support the mantle ring, the number of tuyeres influences the number of columns as previously stated. Either one or two tuyeres are usually placed between each pair of columns, although other arrangements are also used, such as one case where eighteen tuyeres and twelve columns are used. Circumferential spacing of tuyeres on existing furnaces is found to range from 4¼ to 6 ft. For maximum effectiveness, it has been suggested that the spacing should be close enough to make the effective jets in front of the tuyeres contiguous, and that this would require a circumferential spacing of 4 to 4¼ ft. Other engineers feel that a spacing of about 5 ft is satisfactory. Table IX gives the number of tuyeres for various hearth diameters for these two bases, as well as the number found in actual installations.

In one instance on record a furnace with 12 tuyeres was producing 921 tons of iron per day with a blast volume of 67,000 cfm, a coke rate of 1960 lb per ton of iron and a flue dust production of 230 lb per ton of

TABLE IX — NUMBER OF TUYERES FOR VARIOUS HEARTH SIZES

Hearth diameter, ft	Number of tuyeres		
	Actual installations	With 5 ft spacing	With 4 ft spacing
10	....	6	7
12	8	7-8	8
14	8	9	10
16	10-12	10	12
18	10-12	11	14
20	12	12	14-16
22	12-16	14	16
25	12-18	16	18
26	16	16	20
27	....	16-18	20
28½	18	18	20-22

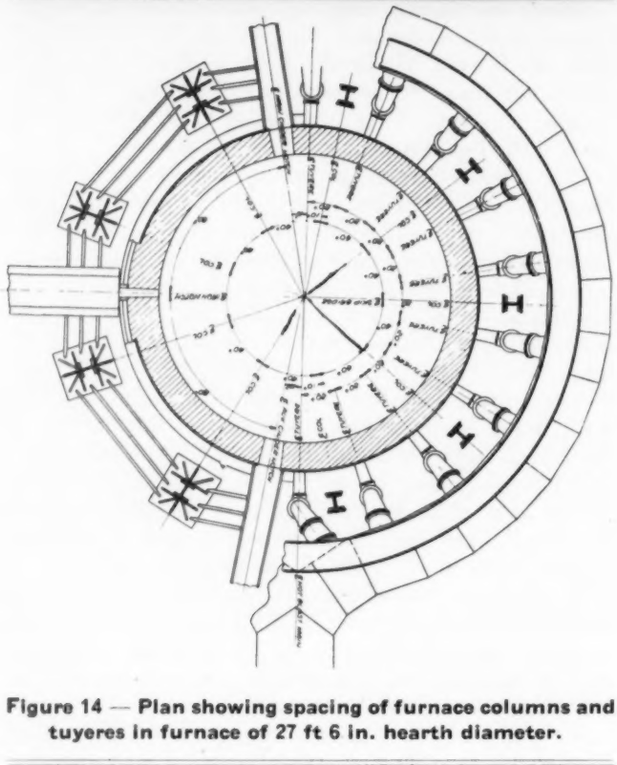


Figure 14 — Plan showing spacing of furnace columns and tuyeres in furnace of 27 ft 6 in. hearth diameter.

iron, and was burning many tuyeres. When the furnace was equipped with 16 tuyeres, production jumped to 1003 tons of iron per day on a blast volume of 65,000 cfm, a coke rate of 1762 lb per ton of iron and a flue dust production of 160 lb per ton of iron. Burnt tuyeres were almost eliminated.

Tuyere area must bear a definite relation to the blast volume, inasmuch as furnace action depends on the action of the blast jets. The majority of American furnace operators stick closely to a total tuyere area giving a figure of 6.75 sq in. per 1000 cfm of blast at standard conditions, although some operators favor areas of 6.25-6.5 sq in. per 1000 cfm. Hence, it is necessary to have a range of tuyere sizes available if blast volume is to be changed materially.

Tuyere life depends on a number of factors of which the principal items are suitability of their design and the quality of metal used in their manufacture, and the extent to which they are cooled with a constant, well distributed flow of reasonably soft, clean water. The cutting action of molten iron upon the tuyere is also a serious factor.

Normal wear by abrasion of the nose of the tuyere proceeds until the thickness of the metal is reduced to a point (perhaps 1/16 in.) where internal water pressure causes rupture.

The hot blast is distributed to the tuyeres from the bustle pipe which rings the furnace through cast steel tuyere stocks 12-16 in. in diameter and cast iron blowpipes 6 or 7 in. in diameter. The bustle pipe is about 6 ft in diameter on the modern furnace and is lined with 9 in. of fireclay brick and 3 in. of insulation, giving an inside diameter of about 4 ft.

A sloping cone ring tops the furnace shaft, and the big bell hopper, which is generally composed of 4 cast steel segments 2-2½ in. thick, fits into the top of this ring. Gas offtakes are located in this cone ring. The small bell hopper is superimposed on the big bell hopper. These items will be subsequently discussed in more detail.

BLAST FURNACE REFRACTORIES

Blast furnace refractories should be high grade brick, carefully made to accurate and uniform size, and suited chemically and physically for their specific application. An adequate testimonial to the refractory suppliers is found in records of modern linings, which range up to a production of 3,000,000 or more tons of iron, with 1,000,000-2,000,000 ton runs quite common.

The refractory lining of the blast furnace is composed principally of standard 9 in. and 13½ in. brick in straights, keys, arch and wedge shapes; while the hearth is built up of blocks 18 in. x 9 in. x 4½ in., usually laid on end and arranged so as to break up the joints as much as possible. Large block sizes offer the advantage of fewer joints. Some furnace men prefer to lay bottom block so that the vertical joints are con-

TABLE X — CHARACTERISTICS OF TYPICAL BLAST FURNACE REFRACTORIES

	Application						
	Hearth bosh and bottom	Inwall and pipe	Top	Stove	Stove, superduty	Stove, superduty	Bond clay
Chemical analysis							
Silica, per cent	52.8	53.6	54.8	52.0	51.7	47.1	56.6
Alumina, per cent	39.7	38.2	37.0	41.1	43.1	46.2	30.0
Titania, per cent	2.5	2.4	2.2	2.6	2.2	2.5	
Iron oxide, per cent	2.5	2.7	2.6	2.0	1.2	2.1	2.1
Lime, per cent	0.1	0.2	0.2	0.2	0.3	0.3	0.2
Magnesia, per cent	0.4	0.5	0.5	0.3	0.3	0.3	0.3
Alkalies, per cent	2.2	2.5	2.6	2.0	1.2	1.3	1.3
Ignition loss, per cent	.....	.....	.....	.....	.....	.....	9.6
Pyrometric cone equivalent	32-32½	32	31-32	32-32½	33-34	33-34	30-31
Equivalent temperature, C	1711	1700	1680-1700	1700-1722	1750	1750	1665
Apparent porosity, per cent	14-18	14-17	12-16	17-22	13-16	16-19	.....
Cold crushing strength (flat), psi	3500-6000	4000-6500	4000-7000	2500-4000	4000-6000	3000-4000	.....
Load test — Subsidence (25 psi at 1350 C), per cent	2-5	.....	.....	2-7	2.4-3.2	2-3	.....

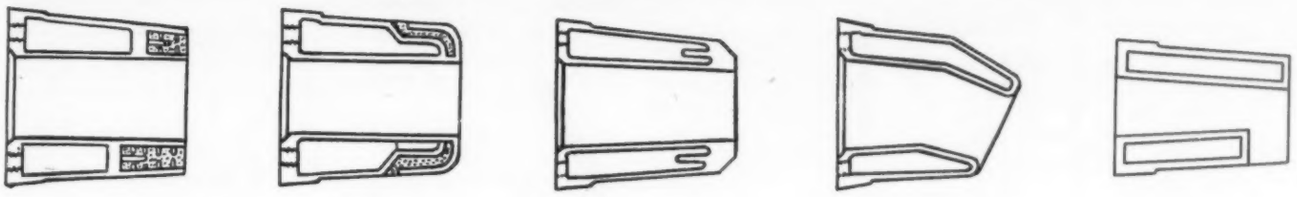


Figure 15 — Sketches showing various types of tuyeres (A) Refractory nose tuyere. (B) Refractory shrouded. tuyere. (C) Heavy nose tuyere. (D) Angle flow tuyere.(E) Split-nose tuyere.

tinuous and the horizontal joints broken, while others lay all blocks of one course at the same level but orient the blocks to preclude any continuous vertical joints.

Bottom blocks must be highly refractory, low in porosity, mechanically strong, and accurately sized. Hard burning is essential so that no secondary shrinkage occurs in the furnace. A careful, tight bricklaying job is necessary to prevent the blocks from being floated. The refractory bottom of the furnace should be at least 13 ft thick. Some furnaces have 10 ft 6 in. of hearth blocks placed on top of a 7 ft layer of second quality ladle brick.

In the hearth and bosh prevail the highest temperatures in the furnace, as well as the scouring action of molten iron and slag. Brick for these locations must therefore possess high refractoriness, high density and low porosity. The hearth linings in many furnaces are 3 to 4 ft in the lower part below the water-cooled section, and about 31½ in. in the upper section. The lining is also usually about 31½ in. thick.

Several hearths and crucible walls have been built with large carbon blocks, and although complete, operating experience is not yet available, material advantages are expected.

As the stock column in the furnace descends through the inwall section of the furnace, abrasion on the brick work progressively decreases while temperature increases. Inwall brick must therefore combine the properties of density, strength, abrasion resistance and high refractoriness. Some operators prefer to divide the inwall section into two parts, using brick particularly resistant to abrasion in the upper part and brick of a more refractory character in the lower part.

The inwall lining is generally 36-48 in. thick, and is laid to just clear the rivet heads of the shell if there is no cooling in this section, and tight against the shell if there is cooling. Loam or granulated slag is widely used as a packing between the shell and the brickwork.

The stockline section of the blast furnace is subjected to severe abrasion from the materials entering the furnace from the bell and hopper. Brick for this section must be dense, tough and of high mechanical strength to withstand shock and abrasion. Lining in the stockline section may range 22½-36 in. in thickness. In addition, this section is protected for a depth of 6-10 ft by some form of wearing plates. Some furnaces use cast iron or cast manganese steel plates imbedded in the brickwork. Others use a stockline armor built of individual plates bolted together to make a complete circular apron which is carried on brackets which permit movement with any expansion of brickwork. Still others use cast or rolled steel plates anchored in concrete.

TABLE XI — BRICK LIST FOR 26 FT 6 IN. FURNACE LINING

Size of brick in in. and type	Hearth and bosh quality	Inwall quality	Top quality
13½ × 6—5 × 3 No. 1 key	25,410	21,780	14,110
13½ × 6—5 × 2½ No. 1 key	1,500	.....	.....
13½ × 6 × 3 straight	37,725	24,660	12,137
13½ × 6 × 2½ straight	1,500	.....	.....
12 × 6—5½ × 3 No. 1 key	4,680	.....	.....
12 × 6 × 3 straight	1,430	.....	.....
9 × 6—5⅜ x 3 No. 1 key	26,640	23,300	9,330
9 × 6 × 3 straight	32,880	24,320	6,880
9 × 4½ × 2½—2¼ No. 1 arch	6,893	.....	.....
9 × 4½ × 2½—1¾ No. 2 arch	1,800	.....	.....
9 × 4½ × 2½—1⅞ No 1 wedge	1,990	.....	.....
9 × 6—5⅜ × 2½ No. 1 key	1,500	.....	.....
9 × 6 × 2½ straight	1,500	.....	.....
9 × 4½ × 2 straight	1,700	.....	.....
9 × 4½ × 1¼ splits	1,700	.....	.....
Bottom block			
18 × 9 × 4½ straight	32,130	.....	.....
Summary for furnace stack			
9 in. equivalent	275,964	182,148	85,361
9 in. equivalent (bottom blocks)	231,336	.....	.....

Grand total, all grades ..... 774,809 — 9 in. equivalents
Fire clay ..... 157 net tons

Brick under furnace column bases:
9 × 4½ × 2½ straight, hard-burned, high-strength 104,800
Brick above furnace column bases:
9 × 4½ × 2½ straight, ladle quality 164,860
Fire clay for above ..... 55 net tons

Brick for dust catcher, downcomers, etc. (Second quality):
9 × 4½—4 × 2½ No. 1 key 40,450
9 × 4½ × 2½—2⅛ No. 1 arch 53,150
9 × 4½ × 2½ straight 65,300
Total 9 in. equivalents 158,900
Fireclay for above ..... 32½ net tons

Brick for stove flue lining. (Second quality):
9 × 4½ × 2½—1⅞ No. 1 wedge 13,250
9 × 4½—4 × 2½ No. 1 key 5,690
9 × 4½—3½ × 2½ No. 2 key 840
9 × 4½ × 2½—2⅛ No. 1 arch 8,640
9 × 4½ × 2½—1¾ No. 2 arch 1,152
9 × 4½ × 2½ straight 38,905
Total 9 in. equivalents 68,477
Fireclay for above ..... 14½ net tons

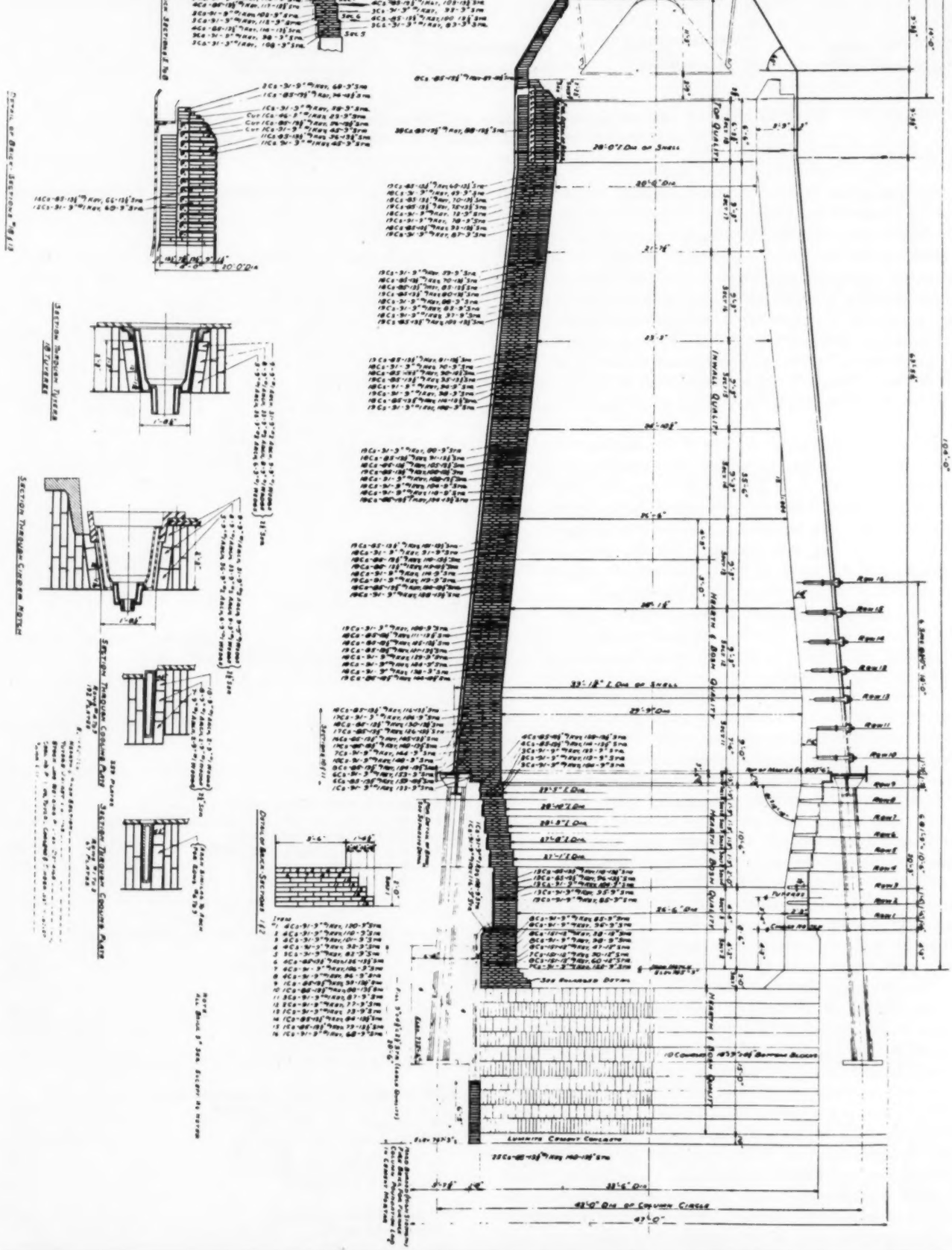
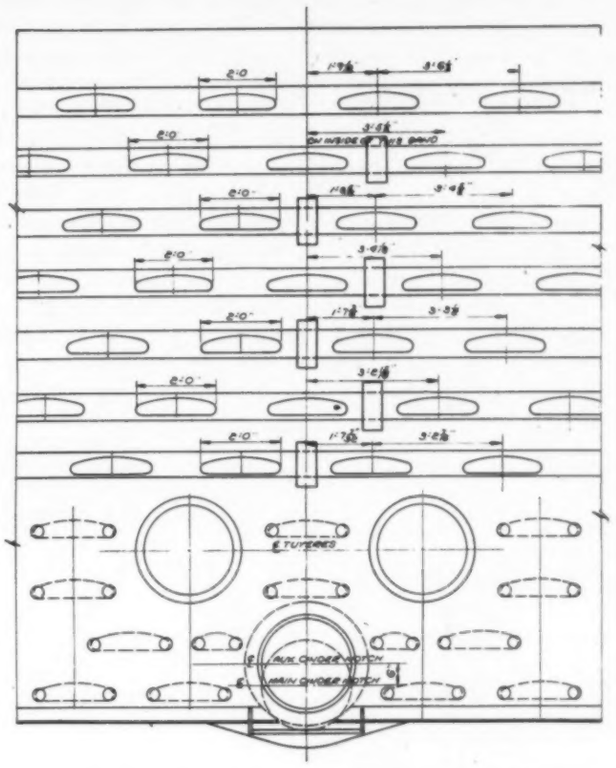


Figure 16 — Drawing showing details of brick lining of ← blast furnace stack.

Figure 17 — Development of furnace bosh, showing arrangement of cooling plates and bosh bands. →



The furnace lining should be plumb and centered in the shell. It is laid up with tight joints, using a thin slurry of best grade fireclay. Approximately 175,000-225,000 lb of fireclay is used in constructing a furnace.

In the hot blast main, bustle pipe, offtakes and downcomers, brick is not subjected to very high temperatures but may be subjected to considerable abrasion, particularly in gas carriers.

Table X shows chemical and physical characteristics typical of the various types of refractories.

The quantity of brick required by the blast furnace naturally varies with the size of the furnace. Figure 16 shows brickwork details for a furnace stack of 26 ft 6 in. hearth diameter, while Table XI shows the overall brick list. In this connection, it should be noted that top and hearth quality brick is used to some extent in the inwall section (see Figure 16). Hence, the count as given in the table is not exactly that for the nominal furnace sections.

Cooling is provided at various locations to preserve the brickwork and, insofar as possible, maintain furnace lines. In general, blast furnace cooling should be kept as low as possible and still afford adequate protection.

As previously mentioned, the hearth is generally cooled by a belt of cast iron staves, 4-6 in. thick and perhaps 14 ft long, with hairpin coils of pipe cast into them. Adequate cooling demands a spacing of about 9 in. for these pipes. An alternate construction using cast steel water cooled segments retained by bands has also been mentioned.

From the level of the cinder notch, copper cooling plates are embedded in the bricklining up through the bosh section and perhaps into the inwall section (Figure 17). This cooling is applied generously around the tuyere zone and gradually decreases as the distance from the tuyeres increases. The rows of plates are spaced about 15 in. apart in the hearth, and 18-24 in. apart in the bosh sections. Circumferential spacing between plates of the same row is about 3-3½ ft, with successive rows staggered. Bosh wall area commonly contains as much as 8-11¼ per cent of cooling plate area, although many furnace men believe 6 per cent is adequate.

The cooling plates in the bosh section may be kept in place by cast iron or steel bosh plate frames, which are in turn held in place by the bosh bands.

Although many operators feel that cooling is unnecessary above the mantle, inwall sections commonly carry cooling for the lower 20-25 ft of their height. Some operators feel that this cooling should be carried to 40 ft above the mantle, particularly in furnaces which will be called upon to produce merchant iron of all kinds. Flat copper plates are usually built into the brickwork, the plates being spaced 3-3½ ft apart circumferentially and the rows, staggered successively, are about 3 ft apart.

Cast iron plates, formerly used for inwall cooling, have largely disappeared, although one furnace operated successfully for years with vertical steel pipes, placed fairly close to the shell, extending for a distance of 18 ft above the mantle.

FURNACE TOP

At the top of the furnace, the uptakes, bleeder stacks and downcomers are directly supported either by the furnace shell or by the top platform. The distributor with its revolving hopper is supported by the furnace top ring. The remainder of the furnace top mechanism, including both bells and their operating rigs, may be supported by the skip bridge, by the bleeder stacks, or by an independent structure separately supported on the top platform. Support by the skip bridge is found only on the older, small furnaces. Many recent furnaces use the bleeder stacks for support, but many furnace men prefer the separate structure. Support by the bleeder stacks requires four bleeder stacks of heavy construction. With an independent top structure, uptake and bleeder stacks may be designed as desired and may be of lighter construction. This construction (see Figure 18) offers more secure bracing and keeps top mechanism in better alignment and adjustment.

The resistance to gas flow at each offtake must be equal if irregular gas flow in the furnace stack is to be minimized. In existing furnaces, the total area of the offtakes varies over an extremely wide range with a top figure of about 150 sq ft. Many engineers favor the largest offtake area possible to obtain, holding that flue dust production is thereby reduced. Offtakes (usually four in number) should be equally spaced, and uptake and downcomer layout should be such as to avoid unequal resistance to gas flow. If two downcomers are used, they should be of about equal length and should

offer the same resistance to gas flow. A number of newer furnaces have used an arrangement calling for a single downcomer. In this layout the four uptakes merge first into two uptakes (one over each side of the furnace) which in turn connect into the single downcomer at a point above the center of the furnace (see Figure 19).

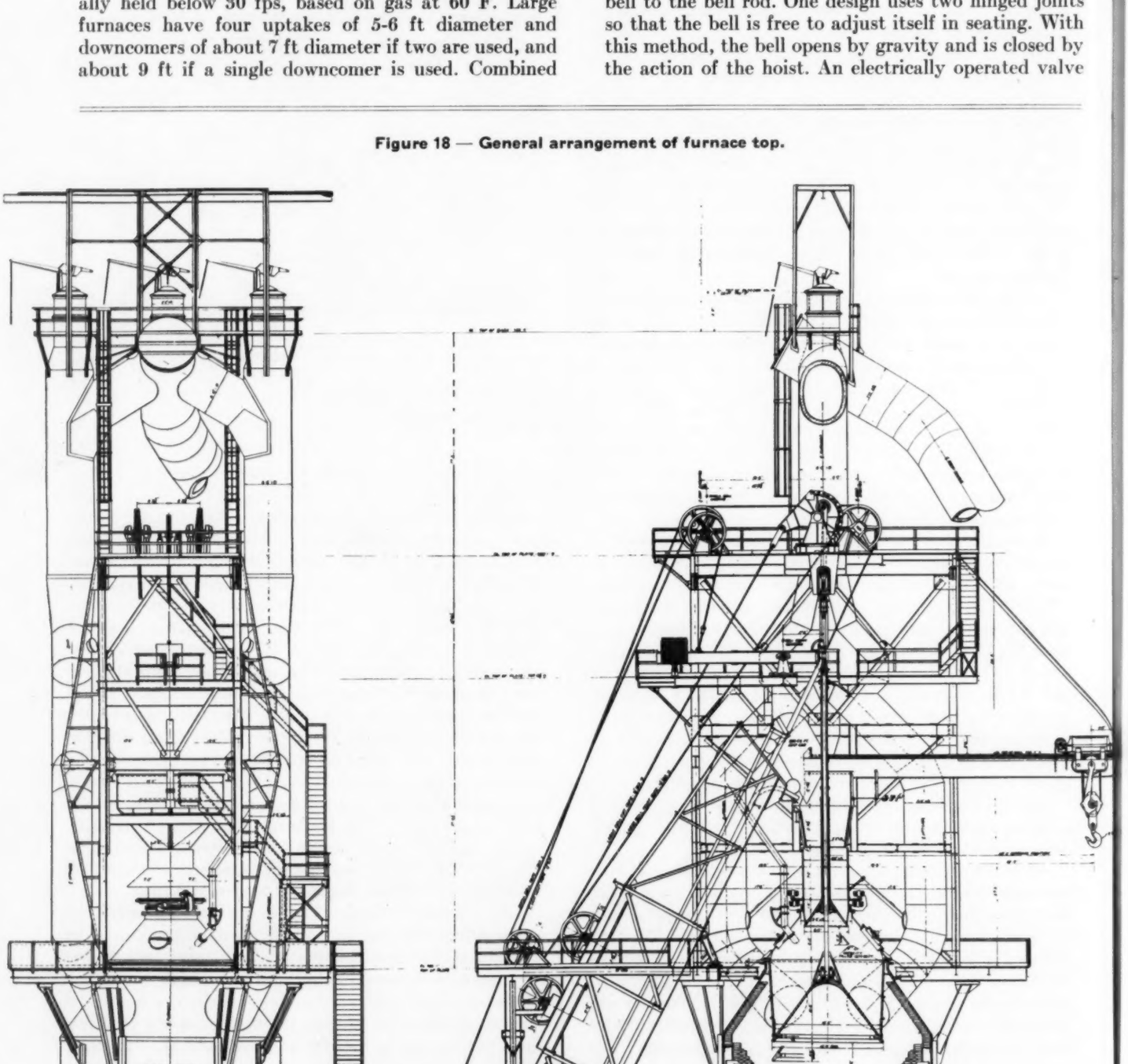
With top temperatures running only 350 F, brick lining is often deemed unnecessary in uptakes and downcomers. The absence of lining gives these lines a greater effective diameter and also allows the gas to cool faster, further reducing its velocity. Wearing plates are placed in the unlined pipes at the necessary points.

Gas velocities in uptakes and downcomers are generally held below 30 fps, based on gas at 60 F. Large furnaces have four uptakes of 5-6 ft diameter and downcomers of about 7 ft diameter if two are used, and about 9 ft if a single downcomer is used. Combined uptake area is about ⅓ of the stockline area; downcomer area ranges 0.2-0.25 of the stockline area.

The large bell is formed by a single casting of conical shape, of about 2¾ in. minimum thickness and with a slope angle of 50-53 degrees from the horizontal. The diameter of the big bell bears a definite relationship to the diameter of the furnace stockline. An annular clearance around the bell of 2 ft to 2 ft 9 in. is usual, although some operators think greater clearance is advantageous and results in reduced flue dust production. Modern furnaces show a ratio of stockline area to big bell area of 1.82-1.85.

Two methods are generally used to fasten the large bell to the bell rod. One design uses two hinged joints so that the bell is free to adjust itself in seating. With this method, the bell opens by gravity and is closed by the action of the hoist. An electrically operated valve

Figure 18 — General arrangement of furnace top.



may be installed in an equalizing line connected above and below the big bell, acting to neutralize furnace pressure which might hold up the big bell and prevent it from dumping. A more recent design uses a rigid connection, with the bell solidly connected to the rod through a bushed socket joint and a stiffening cone. By directing the upper end of the rod in a straight vertical line and properly centering the rod, vertical travel and accurate seating is obtained. This design also opens and closes the bell by direct cable pull, affording positive opening. Travel of the large bell is about 2 or 2½ ft — usually about equal to the annular clearance between bell and stockline.

The small bell is similar in shape and proportions to the large bell, but has a diameter of only 5½ or 6 ft. It has a vertical travel of 2-2¼ ft and is operated through its bell rod, which is hollow and assembled as a sleeve around the big bell rod.

The small bell, or revolving distributor, hopper must have a holding capacity somewhat greater (perhaps 15 per cent) than the capacity of one skip tub. On the other hand, the large bell hopper is called upon to hold a number of skips of material, and its holding capacity may range from 700-1400 cu ft. Many operators insist on large volumes here, so that large charges may be used, which, they feel, sometimes gives improved distribution of the stock.

FURNACE LINES

The present day lines of the modern blast furnace follow certain well-defined proportions which have evolved largely from cut-and-try methods. The modern furnace is characterized by large hearth diameter, great overall height and a low, steep bosh.

Hearth diameters on existing furnaces range from 7 to 28 ft 6 in. Recent units fall principally into 25 ft-27 ft 6 in. diameters, the only size groups which have shown an increase in number of installations.

The total depth of the crucible or hearth section of the modern furnace is about 11 or 12 ft. The majority of the vertical dimensions in this section will average as follows:

Furnace bottom to iron notch	2 ft-2 ft 3 in.
Iron notch to cinder notch	4 ft 8 in.
Iron notch to tuyeres	7 ft 3 in.- 8 ft.
Iron notch to top of crucible	9 ft 3 in.-10 ft 3 in.

Bosh diameters range 1.03-1.34 x hearth diameter (area ratio = 1.06-1.80), with the majority of the recent furnaces showing diameter ratios of 1.1-1.14 (area ratio = 1.2-1.3). Height of the bosh section runs 10-12 ft on the majority of the newer units, with some scattering out between 9 and 14 ft. The bosh angle is of course a result of bosh height and the relationship of bosh and hearth diameters, and generally falls between 80½ and 83½ degrees.

Surmounting the bosh section there is, in practically every case, a straight cylindrical section 7 ft 6 in.-12 ft high and of the same diameter as the bosh. Above this is the inwall section, 53-58 ft high and gradually tapering inward. An inward slope of less than 0.8 in. per ft is considered a light batter, 0.8-1.0 in. per ft a medium batter, and over 1 in. per ft a heavy batter. The majority of the furnaces fall into the medium class; inwall batters of 0.93-0.98 in. per ft are common.

Figure 19 — This construction combines four uptakes into two uptakes and then into a single downcomer.

At the top of the furnace shaft is the stockline section. Here again the diameter is a result of other furnace proportions — in this case, the bosh diameter and the inwall height and batter. Although furnaces are found with stockline diameters of 0.61-0.92 x hearth diameter, recent designs show stocklines of 0.74-0.79 x the hearth diameter (area ratios = 0.55-0.62). The height of this section is 6-8 ft. The top of the stock in the furnace is usually carried about halfway up in this section.

Effective furnace volume is taken as the volume between the tuyere plane and a plane 3 ft below the big bell in its closed position. This volume ranges up to as much as 45,000 cu ft in existing furnaces with modern furnaces showing 75-80 cu ft per sq ft of hearth area, although a spread of 65-130 cu ft per sq ft of hearth area may be found in existing units.

Table XII shows principal dimensions as indicated in Figure 20 for a number of modern furnaces.

CHARGING EQUIPMENT

Charging of raw materials into the furnace depends upon a chain of inter-related equipment consisting in the main of stock bins, scale car, coke screening and measuring device, skip hoist, revolving distributor, small and large bells and bell hoists. As each of these units forms a link in the process of keeping material

TABLE XII — PRINCIPAL DIMENSIONS OF SOME MODERN BLAST FURNACES

Furnace	Hearth Diameter, ft-in. a	Bosh diameter, ft-in. b	Stock-line diameter, ft-in. c	Bottom to iron notch, ft-in. d	Cinder notch to cinder notch, ft-in. e	depth notch to tuyeres, ft-in. f	Hearth (Bend-line to bottom blocks), ft-in. g	Bosh height, ft-in. h	Straight section height, ft-in. k	Inwall section height, ft-in. m	Stock-line height (Bend-line to stock-line, ft-in. n	Working volume, cu ft	Bosh angle, deg-min	Inwall batter, in. per ft	Annular space around big bell, ft-in.
1	20-0	24-0	18-0	2-3	4-6	3-3	11-9	13-0	10-0	45-0	9-0	28,011	81-15	0.800	2-6
2	20-0	23-6	17-6	1-11	4-6	3-4	11-6	11-0	12-2½	42-1⅝	3-10⅜	24,900	80-58	0.850	2-1½
3	22-0	26-0	18-6	2-4	4-7½	3-0½	11-0	11-0	15-0	45-0	4-0⅞	32,100	79-41	1.000	2-3
4	25-0	28-0	19-6	2-0	4-8	3-4	11-9	10-0	9-6	53-9	3-10	37,380	81-28	0.950	2-6
5	25-0	28-0	19-6	2-0	4-8	3-4	11-6	10-0	9-6	53-0	3-6	36,830	81-28	0.960	2-6
6	25-0	28-0	19-6	2-0	4-8	3-4	11-9	10-0	9-6	53-9	3-10	37,380	81-28	0.950	2-6
7	25-0	28-0	18-6	2-0	3-9	3-9	10-6	11-3	9-0	45-7½	1-6¼	32,443	82-29	1.250	2-6
8	25-0	27-9	19-0	2-3	4-8	3-4	12-0	8-3	8-9	46-9	3-0¾	31,826	80-32	1.125	2-6
9	25-0	28-0	19-6	2-0	4-8	3-4	11-6	10-0	8-0	52-6	3-7⅝	35,623	81-28	0.971	2-6
10	25-0	28-0	19-6	1-6	4-6	3-0	10-0	9-0	13-0	47-11⅛	6-8	36,916	80-32	1.005	2-7
11	25-0	28-0	19-0	2-0	4-8	3-4	11-6	10-0	8-0	52-6	3-7	35,249	81-28	1.030	2-3
12	25-6	28-3	19-6	2-3	4-8	3-4	12-6	11-9	5-0	54-0	1-6⅞	35,810	83-28	0.970	2-9
13	25-6	28-3	19-6	2-3	4-8	3-4	12-6	11-9	10-0	54-0	5-0	40,100	83-19	0.972	2-6½
14	25-9	28-9	20-0	2-0	4-8	3-4	11-6	10-0	7-8	52-6	4-7	37,774	81-28	1.000	2-6
15	25-9	28-9	20-0	2-0	4-8	3-4	11-9	10-0	9-6	53-9	3-5¾	39,370	81-28	0.970	2-6
16	26-0	29-6	20-0	2-0	4-8	3-4	11-9	11-9	8-6	54-5¼	3-7½	41,500	81-32	1.040	2-6
17	26-0	29-1¾	20-0	3-0	4-3	3-6	11-6	10-6	10-0	56-0	3-3¾	41,238	81-30	0.980	2-8
18	26-0	29-0	20-0	2-3	4-8	3-4	11-0½	9-7⅞	12-10⅝	47-10⅜	2-6⅝	38,292	81-10	1.128	2-8
19	27-0	30-0	20-0	1-7	3-11	3-5	10-6	12-6	2-6	60-0	6-0	42,364	83-09	1.000	2-6
20	27-0	30-0	19-6	.....	4-8	3-1	.....	12-9	7-0	58-0	.....	43,870	83-17	1.086	2-6½
21	27-3	30-3	20-0	2-0	4-8	3-4	11-6	10-6	6-0	58-6	4-7	42,600	81-28	1.050	2-6
22	27-6	30-6	21-0	2-6	4-8	3-4	11-3	9-9	11-9	52-9	4-6⅛	44,800	81-15	1.080	2-9½

flowing into the furnace, they must be so designed as to prevent any marked bottleneck interfering with the functioning of the charging process. After determining the rate at which the filling of the furnace must be accomplished, each element of the equipment should be selected with the idea of operating it at as moderate a speed as is consistent with conservative practice, and yet keep in step with the other elements — with, of course, a reasonable margin of safety.

Stock bins may be arranged in a long row of single bins or in a double row of bins gated along both sides of the scale car track. Bins should be adequate to hold materials for about 36 hr of regular furnace operation, except the coke bins, where 6-8 hr supply is usual. The shape of the bins should permit free flow of the contents. A steep angle should be used, 52 to 60 degrees for ore bins and 45 degrees or more for coke bins. Sharp corners should be avoided, as should internal stiffening diaphragms. Iron ore may weigh 140-160 lb per cu ft, limestone 90-100 lb per cu ft, and coke 26-32 lb per cu ft. Figures often used in general calculations are 150, 95 and 31 lb per cu ft for ore, stone and coke, respectively. Sinter and roll scale weigh 90-150 lb per cu ft.

With the exception of the central coke bin, all bins have gated openings along the bottoms from end to end. These gates may be manual or mechanical. A type often favored is the rotating drum feeder which is operated from the scale car by a motor-driven pinion which meshes with a ring gear on the drum.

On the furnace high-line above the rows of bins are railroad tracks, over which materials are brought to the bins by transfer cars or regular hopper cars. Some few plants have applied belt conveyors for stocking the bins. The vertical distance from the scale car rail up to the rails on the high-line varies considerably in different

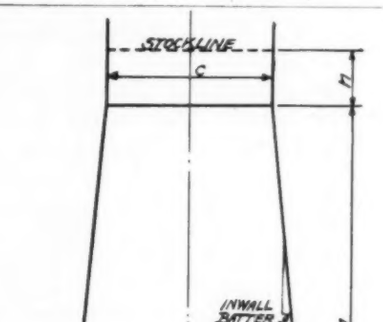


Figure 20 — Sketch of furnace lines as tabulated in Table XII.

plants, but a distance of about 34 ft is favored by many engineers.

A typical bin installation for a modern furnace might consist of a double line of bins. On the ore yard side might be 12 or 13 bins, each 14-16 ft long. These are used principally for iron ore, with perhaps 3 bins holding

Figure 21 — Blast furnace stockhouse, showing hand-operated gates on ore bins.

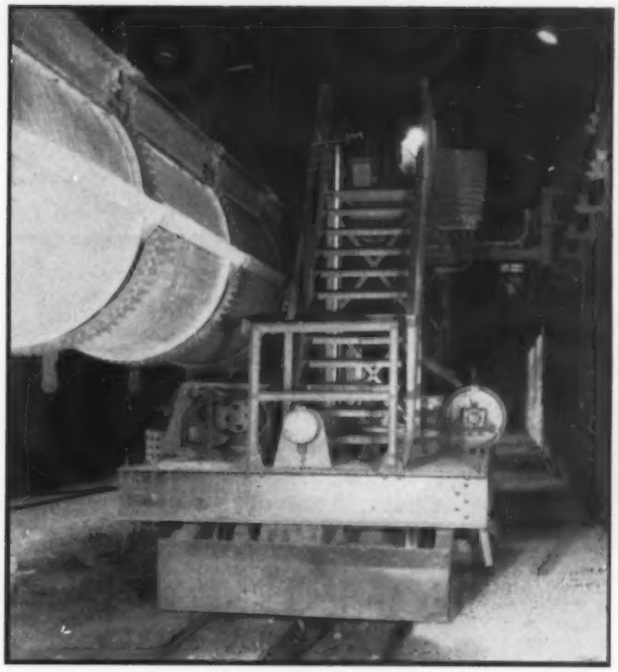


Figure 22 — Roller bin gates, operated by a drive located on the scale car.

limestone. On the furnace side is the central coke bin about 30 ft long (often divided into two compartments) and 10 or 11 of the smaller bins variously holding open hearth slag, roll scale, sinter and scrap, with perhaps several bins devoted to nut coke.

Overhead on the high-line, an ore transfer car may operate on the track on the ore yard side, while a coke transfer car operates on the track on the furnace side of the high-line. A third track may be laid between these two tracks (particularly in plants containing several furnaces), over which miscellaneous material may be brought in standard hopper cars.

The stockhouse floor is usually near the general yard level, and heavy construction is necessary, inasmuch as the stockhouse structure must support the bins, high line tracks and perhaps one end of the ore bridge. In some cases, it must also act as a retaining wall against the piles of iron ore in the ore yard.

Coke is chuted directly from the central coke bin, perhaps through automatic weigh hoppers (Figure 23), into the skip cars. If it is desired to screen the coke just before it enters the skip car, a motor-driven vibrating screen is interposed between the central bin and the measuring hopper. Since coke cannot be screened as rapidly as it can be charged into the skip car, the measuring hopper is a necessity to avoid unnecessary skip delay while screening.

The measuring hopper should contain no obstructions or sharp corners, which might obstruct the flow of coke into the skip car, and should have a lining of brick or manganese steel plates to resist abrasion.

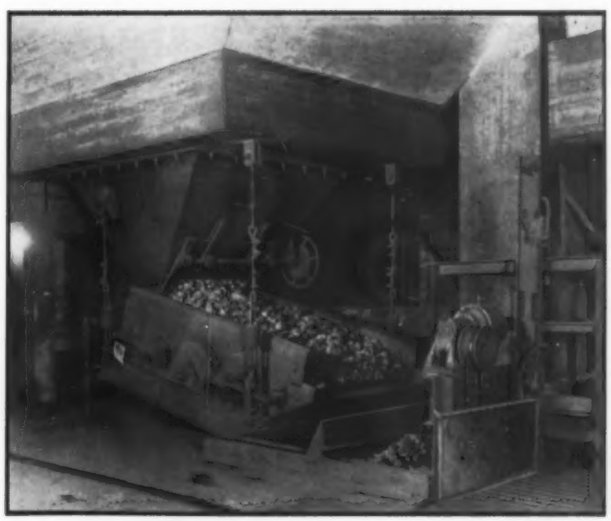
Most measuring hoppers are equipped with scales having an electrical contact which acts to shut off the flow of coke into the hopper when the desired weight has been received.

Some furnace operators believe that, because of varying moisture in the coke, volume measurement gives a more accurate measure of the carbon charged to the furnace. Volume measurement is obtained by means of an electrode hung from the side of the weigh hopper. The position of the electrode is fixed to give the desired volume of coke when the coke level in the hopper rises to make contact with the electrode, causing a relay to operate and shut off the flow of coke. This same method of volume measurement can also be applied to the skip car in case the screen and measuring hopper is not installed.

SCALE CAR

The function of the scale car is to take the proper amount of ore and limestone from the bins and trans-

Figure 23 — Coke from the bin passes over this vibrating screen and into a measuring hopper.



port it to the skip car in the loading pit. The scale car is generally of double-compartment type, with each hopper at least equal in volume to the skip car. Hoppers range 180-250 cu ft in volume, with modern units largely at the higher figure. Some few units are even larger, up to 300-325 cu ft.

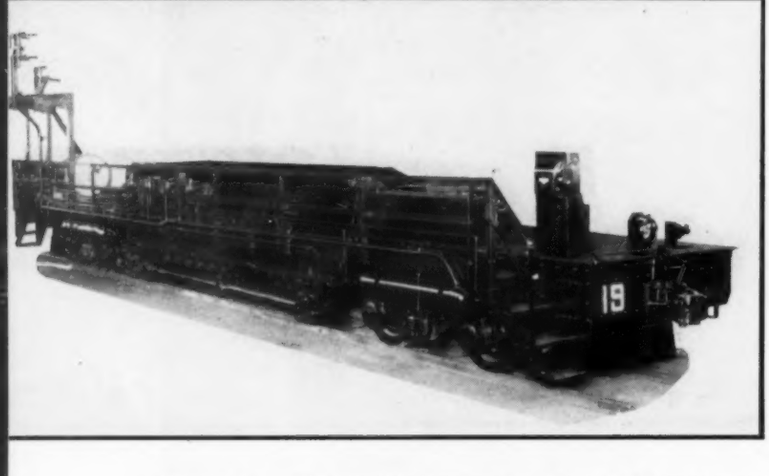


Figure 24 — This double hopper scale car, of 35 tons capacity, is the largest which has been built.

The car may be either of bottom dump type or side discharge type (the former is more common), electrically driven at a maximum speed of about 600 fpm. With heavy, well supported rails (and no sharp curves), 4-wheel cars are satisfactory, with each axle driven by a separate motor. Where it is desired to reduce rail and wheel load, 8-wheel cars having two 4-wheel swivel trucks may be used. Drive motors are usually under automatic plugging control, with air brakes also provided.

The heavy duty weighing scales with which these cars are equipped are especially designed for this service, with a large scale dial for easy reading, and an automatic weight recording attachment which gives a chart or tape record of every charge.

Discharge gates on the car may be operated either pneumatically or hydraulically, with the former receiving preference. The pneumatic power is provided by a compressor which also supplies the air brakes. Particularly important with the double-hopper cars is the interlocking of these discharge gates so that they cannot be opened unless spotted over a skip car which is in position to receive the load from the car hopper.

The scale car usually carries the operating mechanism for mechanically operated bin gates. This mechanism may be in the nature of a pneumatically operated cylinder or air jack, or an electrically driven engaging mechanism for roller bin gates.

The operator rides the car, stationed either above the hoppers or on one side of the car, depending on the type of stock bins installed.

In many cases it is the scale car's part of the filling cycle that is the limiting factor.

SKIP HOIST

Furnaces are normally burdened with alternate layers of ferrous material and coke. The depth of the coke layer, though varying at different plants, may be approximately 15 in. From this depth and for a given stockline diameter, the volume of the coke charge may be calculated, and, with coke weighing 31 lb per cu ft, the weight of the coke charge may be determined. This may range 5,000 to 22,000 lb, which, at an average coke rate may make "T" tons of pig iron. The ore requirements for this amount of iron (at 100 per cent ore charge, 51 per cent iron in the ore, 93 per cent iron in the metal and 4 per cent loss of ore in flue dust) equal:

$$\frac{T \times .93 \times 2000}{.51 \times .96}$$

which, at 150 lb per cu ft, occupies a certain volume.

In normal practice, the coke volume equals 2-2.25 times the ore volume as calculated by the above method.

Ore, coke and stone are charged into the furnace according to a predetermined filling cycle selected by the operator. Such cycles are usually arrived at by trial and error, and vary widely. Some typical cycles follow:

O O S C C/
O S C C/O O S C C/

C C C/O O S

O C C/

O C C/O S C C/

S C C S C C S C

The letters designate a skipload of the material designated by the initial; the diagonal indicates a dump of the large bell. Each complete group constitutes a round.

When it is considered that an average round for a large furnace may contain materials sufficient to produce about 15 tons of iron, it is soon apparent that a modern furnace producing 1000-1500 tons of iron per day requires some 480-700 skiploads of material per day which means from 180 to 125 seconds for each skip trip. It should be borne in mind that this time must also include skip loading intervals, which may amount to about 10 sec per skip trip.

The ability of the skip hoist to keep a blast furnace filled depends principally upon the size of the skip tubs and upon the filling cycle selected. Figure 25 shows the number of skip trips per day necessary to maintain various production rates, when using various filling cycles. The curves are based on skips filled to 95 per cent of their volume when charging coke, with the ore skips adjusted to correspond. The variation in the number of skip trips for a given tonnage with different filling cycles is self-evident. In general, the higher the ratio of coke skips to total skips, the fewer the skip trips required. The advantage of skip tubs of 250 cu ft capacity is readily seen.

The time required for a skip trip depends upon the length of the trip (which may range 175-225 ft) the full running speed, and the reduced speeds at the start and finish of the trip. For a travel of 200 ft, about 45 sec is required for the trip with a rope speed of 350 fpm.

Increasing rope speed to 500 fpm cuts this time to 37.2 sec, and a 600 fpm rope speed gives a time of about 34 sec. Hence, high rope speeds result in only a nominal and perhaps negligible gain in charging capacity, while demanding a much larger drive and heavier rope.

Proper coordination between the skip hoist and furnace top mechanisms is of greater significance than high skip hoist speed in attaining maximum charging potentialities. The most advantageous speed for the skip hoist of a typical blast furnace, in terms of charging capacity, is one giving a skip cycle of 40-45 sec. Little if anything is gained through reducing the time below 40 seconds inasmuch as the skip must then be delayed waiting for the distributor to complete its rotation. A hoist having a nominal running speed of 300 fpm can complete a skip cycle involving a trip of 175 ft in about 45 sec. To complete a 225 ft trip in the same time, a nominal running speed of about 400 fpm is required.

Figure 26 shows an overall comparison of two charging cycles using a seven-skip round consisting of OCC/OSCC/ with skip cycles of 45 and 35 sec, respectively. The faster cycle entails delaying the skip until the distributor completes its movement. In both cases, the time allowed for discharging is 10 sec; the time allowed for charging coke is 15 sec and for ore, 10 sec. It is also assumed that the scale car requires 180 sec to load ore and stone into two compartments and 120 sec to load ore only into one compartment. Both diagrams in the figure refer to 180 degree rotation of the distributor.

The diagrams show that the scale car is the bottleneck during the first half of the round and that the 35 sec skip cycle, requiring about 70 per cent increase in the rope speed of the skip, effects no saving in time for the total round. To permit the use of drive equipment of moderate size, to minimize and level off the power demand and to reduce wear and tear in general, the speed of the skip hoist should not be higher than necessary to enable it to perform its function, including marginal capacity for forced charging.

It is generally thought that rope speeds not exceeding 400 fpm should be used for most skip hoists. Some engineers prefer to operate the skip hoist normally at a somewhat moderated speed, say about 50 fpm under the maximum. The maximum speed may then be resorted to when forced charging becomes necessary.

All modern skip hoists are motor driven. Motor size

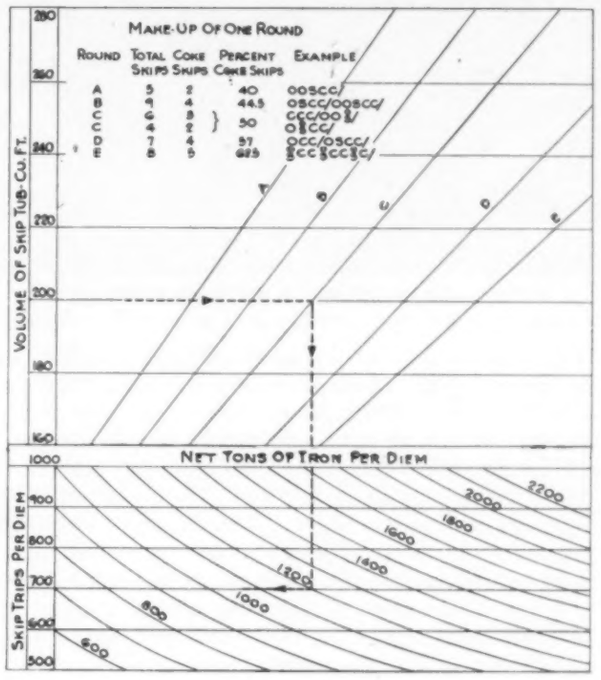
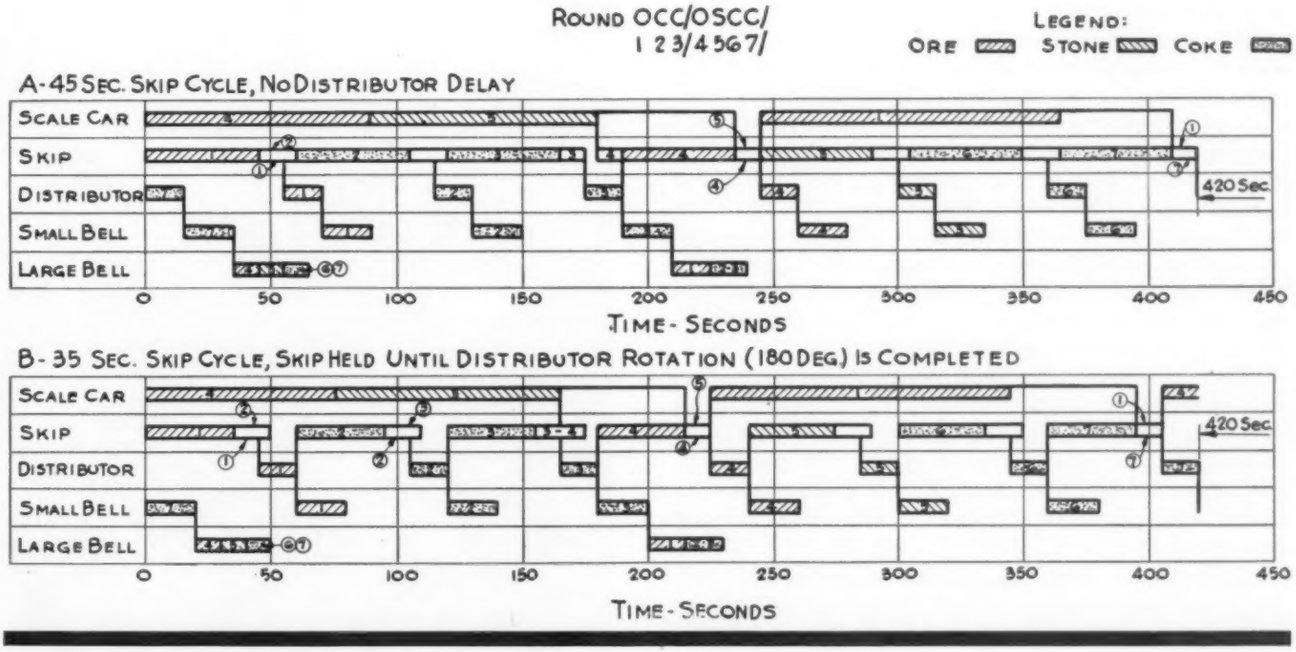

MAKE-UP OF ONE ROUND
ROUND TOTAL SKIPS COKE SKIPS PERCENT COKE SKIPS EXAMPLE
A 5 2 40 OOSCC/
B 9 4 44.5 OSCC/OOSCC/
C 6 3 50 OCC/OSCC/
D 7 4 57 OCC/OSCC/
E 8 5 625 OCC/OCC/OC/
VOLUME OF SKIP TUB-CU. FT.
NET TONS OF IRON PER DIEM
SKIP TRIPS PER DIEM

Figure 25 — Chart giving number of skip trips required per day for various rates of production and filling cycles.

▲

Figure 26 — Comparison of charging schedules with 45 and 35 second skip cycles.



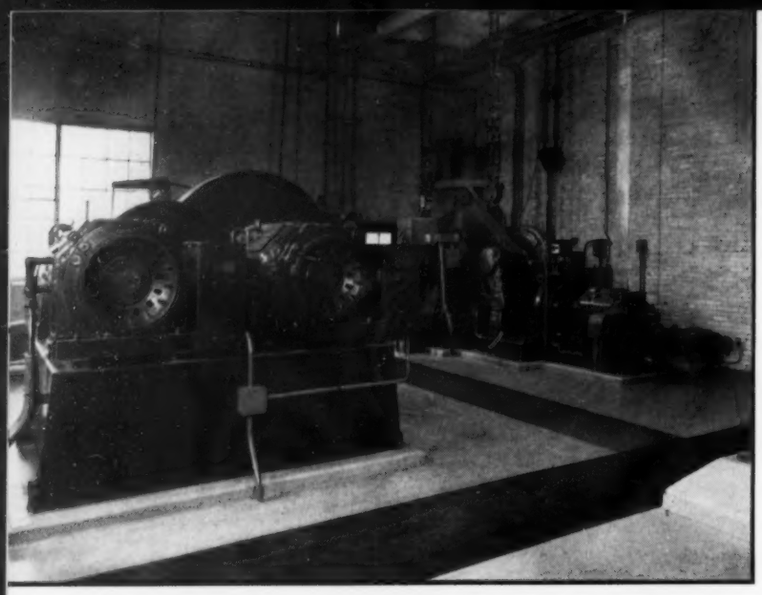


Figure 27 — View in hoist house, with skip hoist in foreground and motor-driven bell hoist in background.

is dictated largely by torque requirements rather than by the rms load, which is usually less than 100 hp. A skip hoist with a 400 fpm rope speed has a requirement of perhaps 250 hp with a starting peak of 375 hp. A 600 fpm rope speed may require a starting peak of over 500 hp, and a running power of 375 hp. Many of the older units employ a single d-c motor drive of 200-250 hp, operating under magnetic contactor control from a constant voltage supply. Recent trends, however, seem to favor the dual-drive, using two motors of about 150 hp each. Such drives are now controlled either under an adjustable voltage system, wherein a motor-generator set supplies power to the drive motor, or under a constant voltage system using two shunt-wound motors with series-parallel connections supplemented by field-forcing for use in starting and by field-weakening for running.

For rope speeds of 450 fpm or more, adjustable voltage is preferable. This system is considerably more expensive, however, unless there is a lack of d-c power at the site. Both of the dual-drive systems are reliable and have satisfactory operating characteristics.

Many modern installations equip the hoist house with a washed air ventilating system which cools the drive and keeps the room under positive pressure to exclude dirt. Such rooms often contain no windows, and instead of large service doors they may have removable floor slabs.

Skip cars are of two general designs, the bail type and the trailer type. The former is less expensive and does not require elaborate guide rails on the skip bridge. The trailer type uses fewer sheaves and simpler reaving, but requires a much deeper skip pit. The bail type skip car is in wider use than the trailer type.

Skip car capacity on the modern blast furnace has centered largely on 200 cu ft, although larger sizes (up to 250 cu ft) have been used in some few cases, and as is shown previously in this discussion, is of definite advantage in filling large furnaces. Also, large skip tubs permit the use of liberal coke charges, but do not necessitate it.

Skip wheels and axles should be designed so that each wheel can revolve independently. Anti-friction bearings are generally applied to the wheels.

The skip bridge is usually of truss design, either self-supporting through a structural shear leg, free from the furnace stack, or supported, through pin connections at the lower end, by foundations at the skip pit and, through a pin-connected link at the upper end, by the furnace stack. The first method is used to lighten the load on the stack and eliminate lateral thrust against it. The second method is used by those who feel that proper dumping relations require the upper end of the bridge to be tied in to the furnace top. This method also permits a somewhat lighter construction of the bridge.

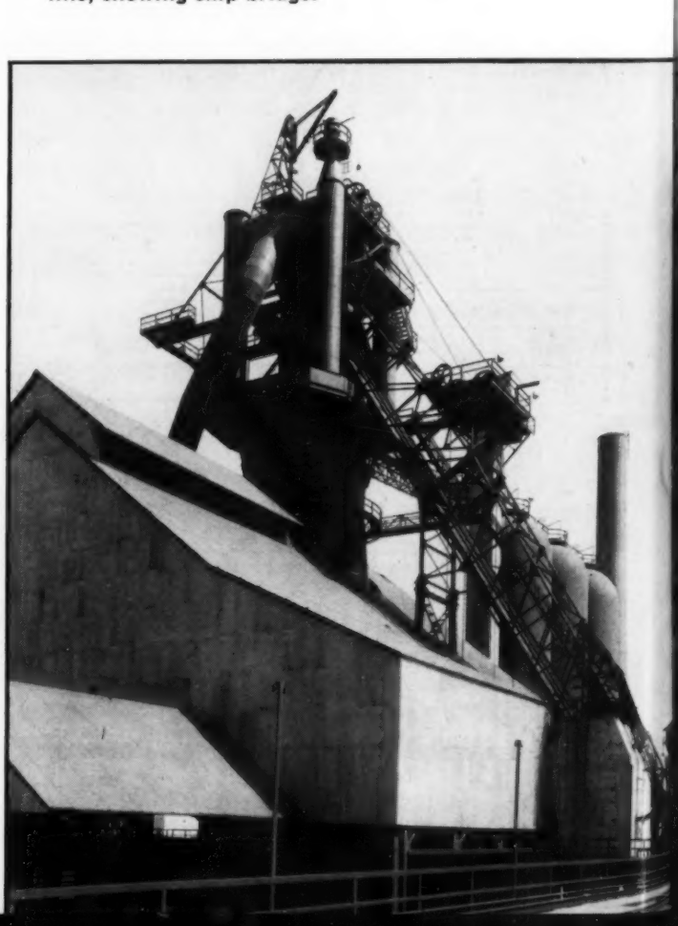
Many engineers contend that the bridge should not be attached to the furnace or supported by the furnace, and probably just as many think its support by the furnace is advantageous.

STOCK DISTRIBUTOR

The use of the McKee furnace top with its revolving distributor (Figure 29) is almost universal on the modern blast furnace. This distributor, by its rotation, successively deposits material in six positions spaced 60 degrees apart around the top, making each sector of the furnace's horizontal cross-section receive successive charges. This tends to make the distribution of stock symmetrical, with the same proportion of lump and fines in each segment.

Generally, all of the skip loads that are charged on the large bell for one round are rotated through the same angle. Then the large bell is dumped, and the loads of the next round are rotated 60 degrees farther. The third round would be rotated 120 degrees; the fourth, 180 degrees; the fifth, 240 degrees; and the

Figure 28 — View of modern blast furnace from the high-line, showing skip bridge.



sixth, 300 degrees. This completes a complete cycle of top rotation, after which the cycle is repeated.

Much time can be saved in distributor rotation if the operation is reversing, so that angles of more than 180 degrees are reached by reverse rotation through the supplementary angle. The distributor is geared so as to make a 180 degree trip in about 16 sec.

The distributor control functions in three ways:

1. It selects the angle through which the top is to be rotated.
2. It initiates distributor operation at the proper time in the cycle.
3. It measures the angle through which the distributor is rotated.

Should the operator desire to charge split rounds, it may be necessary to change the angle of rotation after every second dump of the bell. This can be easily accomplished by changing the gear ratio between the program controls of the large bell and the distributor.

Distributor control is generally designed in conformity with the following:

Time of skip cycle at maximum speed, sec	Distributor angle	Delay skip until distributor has traversed
Over 45	....	None
40-45	180	60°
35-40	180	120°
	120	60°
	240	60°
Under 35	For all distributor angles, hold skip until distributor has completed rotation.	

Figure 29 — The revolving distributor is universally used on the top of modern furnaces.

Figure 30 — Pneumatic bell hoists and motor operated valves for their control.

The distributor, bells, etc. must be accurately centered on the furnace top. Many operators adjust the top after the furnace has been filled to about 30 ft from the top.

BELL HOISTS

Bell operation may be effected by steam, oil-hydraulic or pneumatic cylinders or by electrically operated hoists. On some old furnaces, the large bell is held closed by a weight, which is lifted by a steam cylinder to open the bell, while the small bell is operated by a double-acting steam cylinder. Condensation of steam in the cylinders results in sluggish operation.

A later development was the use of oil-hydraulic cylinders, which gave smoother operation and accurate speed control, but required oil pumps, lines and an accumulator, while the oil constituted a fire hazard.

The pneumatic hoist (Figure 30), which has been widely applied on many recently constructed furnaces, uses two vertical cylinders, one of about 50 in. in diameter for the large bell and one about 24 in. in diameter for the small bell. The cylinders are double-acting, so that both bells are held closed by the combination of air pressure and the counterweight effect of the cylinder itself. When the cylinder is raised by air pressure on the other side of the stationary piston, tension on the bell cable is released so that the bell opens by gravity.

Air to operate the pneumatic cylinders comes normally from the cold blast air which is controlled through a reducing valve to give 15 psi pressure. As a standby, compressed air from the general plant system is brought in and reduced by another reducing valve to 14½ psi, so that the compressed air automatically takes over the operation should the cold blast pressure drop. Complete failure of all air pressure causes loaded bells to open and dump their loads and then reclose by the counterweight action of the cylinders. Only a few cubic feet of air, at a rate of 30-35 cfm, are required for a complete

movement of the bell cylinder. Two three-way valves, operated through a crank by a ½ hp motor, control air flowing in and out of the two ends of the hoist cylinder. The motor may be controlled from a push-button or from automatic charging control.

Should top pressure beneath the large bell be so high as to support the large bell and its load when the large bell cylinder operates to open the bell, the resultant slack cable trips a "slack-cable" switch, which reverses the air supply and holds the large bell closed until the slack-cable switch is reset and the trouble eliminated.

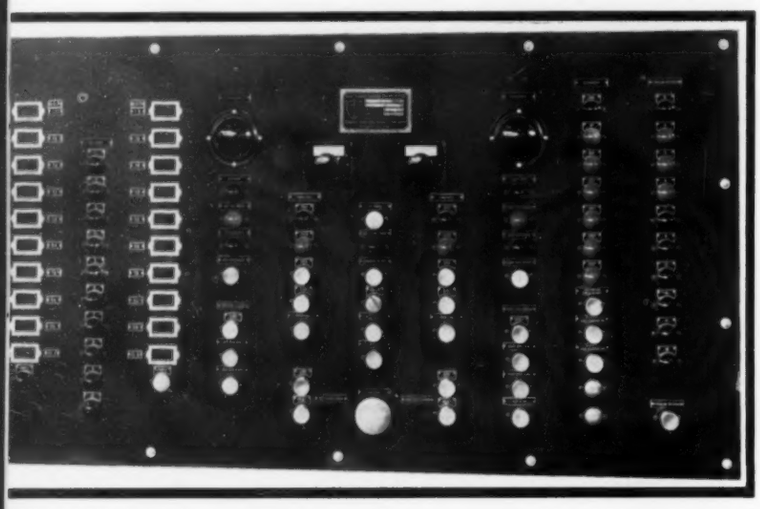


Figure 31 — Master panel for blast furnace charging control, distributor control, automatic coke charging control and stockline recorder.

Pneumatic bell hoists provide smooth operation, with accurate speed control during both opening and closing movement. By throttling discharge air through the separate discharge lines provided for each travel of the hoist cylinder, speed is easily adjusted in either direction. Cables may stretch 5 or 6 in. without losing the seal on the bell. The double action of the cylinder tends to cushion bell operation, while the air cushion also acts to absorb much of the shock occurring from explosions between the bells. Relief valves mounted on the cylinder act to relieve the pressure should the air in the cylinder be compressed much above normal pressure.

Electric bell hoists have used several principles to convert the high speed rotary motion of the motor to the slow reciprocating motion needed for bell operation. An early design used a long screw with a traveling nut. Later designs used various arrangements of cranks. Some recent installations use a single unit, double-drum hoist driven by a single adjustable speed d-c motor. Mounted on the hoist engine shaft are two dogs which engage the two drums in such a manner that when the shaft is revolved in one direction, one dog engages one drum so as to cause the small bell to open. As the shaft returns to the neutral position, the small bell closes through the action of a counterweight. When the shaft is rotated in the other direction, the second dog engages the second drum, and the large bell is opened. The large bell is likewise closed by a counterweight. Both counterweights are usually placed at yard level although the small bell counterweight is sometimes put on the beam at the top of the furnace.

Thus, if the bell is solidly connected to its rod, as in the recent rigid design, positive opening of the bell is assured, because the bell is opened by positive tension on the cable, so as to overcome any pressure tending to hold the bell closed.

Either the pneumatic or the electrical bell hoist gives satisfactory service and either type can be operated automatically from the charging control system. The selection between them has been the subject of much debate and becomes largely a matter of individual preference.

Suitable timing devices are provided on bell hoists which cause the bells to remain open a definite time to permit all material to be discharged from the bells before they are closed. Typical time on the bells may run somewhat as follows:

	Small Bell, sec	Large Bell, sec
Open	8	12
Pause	4	6
Close	8	12
Total	20	30

The pause intervals on the small bell may range 4-8 sec, and on the large bell, 6-13 sec.

Automatic recording of stockline height is applied to practically all modern blast furnaces. This measurement is made by a test rod which descends through the top of furnace to rest on top of the burden. The rod is carried on a cable connected to a motor-driven winch. The test rod may ride continuously on the stock in the furnace, being pulled up only when it is time for the large bell to be opened, or it may measure intermittently, being periodically lowered to the burden and then immediately withdrawn. The recording meter is operated from the winch through a flexible drive shaft or through synchronous transmitting devices. In addition to the recording meter, lamp targets are provided to give the operator an easily observed indication.

Over one-third of the existing furnaces in the United States are equipped with a charging control which coordinates and interlocks the operations of the skip hoist, distributor, bell hoists and stockline recorder. This control performs the following functions:

1. It acts to select the proper direction of rotation for the skip hoist and interlocks its operation with other operations in the charging sequence.
2. It initiates the distributor operation through the medium of the distributor control and interlocks the distributor operation with the skip hoist and the small bell operation.
3. It controls the small bell hoist operation, sequences its operation with the skip hoist, and interlocks it with the operation of the large bell.
4. It initiates the hoisting of the stockline recorder test rod before the large bell opens.
5. It controls the large bell operation after the small bell has made a preset number of dumps.

The basic elements of the charging control are motor-

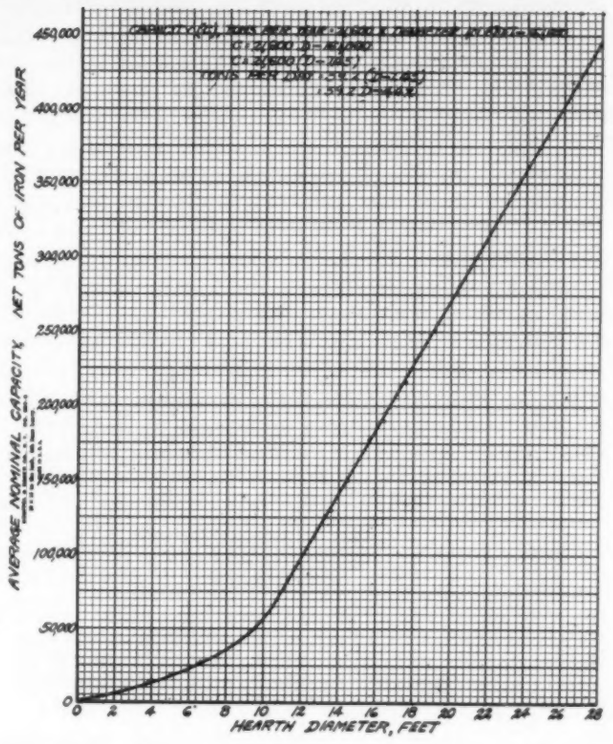


Figure 32 — Chart showing average nominal rated capacity vs hearth diameter for all blast furnaces in the United States.

driven program switches (rotating cam switches), one for controlling the small bell and skip, another for counting operations of the small bell, and a third for controlling the large bell and stockline recorder.

Automatic coke charging, which is practically a necessity on large furnaces, relieves the scale car operator of that duty and speeds up the charging operation. The function of the control is to select the skips to be filled with coke, load the desired skip with coke after it arrives in the pit, and when the loading is completed, it automatically sends the skip to the top of the furnace. The control may be fully automatic, with its program coordinated with the other charging control, so as to require no attention from the operator, or it may be a control which must be preset and is automatic only after a push-button is operated to initiate the operation. The preset control is more flexible, as the operator can change the order of coke charges without resetting control switches. The full automatic control, however, prevents the operator from forgetting to set up a coke charge.

As there are times when it is desirable to cut out automatic control of charging equipment, the control can be cut out and the various operations initiated from push buttons.

FURNACE CAPACITY

The capacity of a blast furnace has been aptly defined as "what you can get out of it." There seems to be no practical limit that can be used as far as the thermal or metallurgical action in the hearth or bosh of the furnace. Rather, limits seem to be gas velocity in the shaft and the pressure drop in the furnace. In the search for something more definite than this, the hearth diameter or area has been widely used. A figure of 2.45 net tons of iron per sq ft of hearth per day has often been advanced as a good average figure. However, records from a number of furnaces of various size show production figures as follows:

Hearth diameter, ft - in.	Net tons of iron per sq ft of hearth per day
12 - 7½	3.10
15 - 7	2.65
17 - 3	2.51
19 - 0	2.37
20 - 9	2.32
21 - 0	2.29

Wm. Haven has advanced the formula: Gross tons of iron per day = (hearth diameter, ft × 60) — 450 = 60 (hearth diameter, ft — 7.5). Converted to net tons, this becomes 67 (hearth diameter, ft — 7.5). This formula agrees in form with the average nominal capacity of existing furnaces as set by the operating companies (see Figure 32), but it is about 12 per cent higher, and probably closer to actual practice.

On the basis of the Haven formula, the capacities of furnaces of various hearth diameters are as follows:

Hearth diameter, ft	Net tons of iron per day
15	500
18	700
20	840
25	1170
27	1300

Based on effective working volume, iron capacity of various sizes of furnaces is found to be approximately as follows:

Effective volume, cu ft	Net tons of iron per day
20,000	700
30,000	1000
40,000	1300
45,000	1500

Reduced to unit figures, this gives 30-35 net tons of iron per 1000 cu ft of furnace volume, this value decreasing as the furnace size increases.

The influence of furnace volume upon capacity was well demonstrated by the rehabilitation of a furnace during which the volume was increased 33 per cent without changing the hearth size. After the change, this furnace produced 10 per cent more iron on the same blast volume and daily coke consumption previously used. It was further possible to increase the blast, obtaining the following changes:

	Old	New
Blast volume, cfm	70,000	80,000
Net tons of iron per day	950	1,125
Lb of coke per net ton of iron	1,925	1,838
Lb of dust made per ton of iron	250	153

Actually, hearth size is really a measure of coke-burning capacity rather than of pig iron capacity. Several empirical formulae have been developed for this:

1. Lb of coke per day = 4775 × area of tuyere plane, sq ft.
2. Lb of coke per day = 108,000 (hearth diameter, ft —7.5).
3. Lb of coke per day = 6300 × area of a 6 ft annular band in front of tuyere noses.

Formula 1 (advanced by F. H. Willcox) gives results too low for small furnaces and too high for large furnaces. It is approximately right for a 23 ft hearth.

Formula 2 gives low results over the entire range of sizes.

Formula 3 (derived by Owen Rice) is based on the premise that action before the tuyeres does not extend beyond 6 ft from the tuyere nose, and on observations that furnaces of 14 ft or less hearth diameter (which gives a tuyere plane radius of approximately 6 ft or less, allowing for projection of tuyeres into the furnace) use about 6300 lb of coke per day per sq ft of tuyere plane area.

If the tuyeres are assumed to project into the furnace 9 in. and formula 3 is reduced to its simplest terms, we have:

4. Lb of coke per day = 119,000 (hearth diameter —7.5).

which is the same as formula 2 but with a slightly higher constant. In this form the simplified formula holds only with hearth diameters of about 14 ft or more, which is the point where the entire tuyere plane area becomes effective.

Formula 3 (or 4) agrees closely with observed practice, as may be noted from the following figures:

Hearth diameter, ft - in.	Coke-burning capacity, lb per day	
	Typical practice	Calculated value
7 - 2	192,000	187,000
13 - 6	750,000	770,000
18 - 6	1,280,000	1,310,000
20 - 0	1,480,000	1,490,000
25 - 0	2,030,000	2,080,000
27 - 0	2,260,000	2,300,000

Another index often used to determine blast furnace capacity is the rate at which air can be blown to it. Here again a diversity of results are to be found. One operator gives, as a practical blowing limit, 150 cfm per sq ft of hearth with Mesabi ores and coke made from high-volatile coal alone, and 160 cfm per sq ft or more if an appreciable quantity of low volatile coal is used in coking.

Data reported from a number of furnaces show maximum blowing rates consistent with good operation to vary from 165-180 cfm per sq ft of hearth area on small furnaces down to 125-140 cfm per sq ft on large furnaces. Based on effective working volume of the furnace, these rates become 225-240 cfm per cu ft for small furnaces and 175-190 cfm for large furnaces. On the other hand, the blast volumes per sq ft of stockline area run rather consistently at values between 210-240 cfm, with an average of 227 cfm. On this basis, it is suggested that 227 × stockline area, sq ft = blast capacity of the furnace. At 52 cu ft of air per lb of coke, 227 × 1440 ÷ 52 = 6300 lb of coke per day per sq ft of stockline area, which is the same consumption previously given for the area of the 6 ft annular ring in front of the tuyere noses — an indication bearing out the thoughts of some engineers that the stockline area should be equal to that of the 6 ft annular ring in front of the tuyere noses. If this plan were followed, stockline diameters on large furnaces would have to be increased above present practice, as indicated by the following:

Hearth diameter, ft	Stockline diameter, ft - in.	
	Recommended	Actual
12	10 - 10	11 - 6
14	12 - 6	13 - 0 to 15 - 6
16	14 - 4	14 - 6 to 16 - 0
18	16 - 0	16 - 0 to 18 - 0
20	17 - 3	17 - 0 to 18 - 0
22	18 - 9	18 - 6
25	20 - 4	19 - 0 to 20 - 0
26	21 - 0	20 - 0
27	21 - 6	19 - 6 to 20 - 0
28	22 - 0	19 - 0 to 21 - 0

Some furnace men prefer to base coke-burning capacity upon effective furnace volume. A figure of 60 lb of coke per day per cu ft has been in use for many years. Operating figures, however, show blast volumes ranging 1.75-2.75 cfm per cu ft of effective furnace volume for large and small furnaces respectively, and inasmuch as the air requirements of the blast furnace are fairly close to 52 cu ft per lb of coke, a constant value for coke consumption does not seem applicable.

It has often been suggested, however, that the time of contact in the furnace between the reducing gases and the ore has a marked effect on fuel economy. Owen Rice has set up the following formula for the retention time of gas in the furnace:

$$T = \frac{0.36\ V}{167 \times \frac{L}{86{,}400}}$$

$$= \frac{185\ V}{L}$$

where T = retention time, seconds.
V = effective volume of furnace, cu ft.
L = lb of coke burned per day.
0.36 = probable voids in typical Lake ore burden.
167 = cu ft of gas per lb of 88.5 per cent fixed carbon coke at the average pressure and temperature prevailing in the furnace.
86,400 = seconds in a day.

Coupling this formula with typical operating practice on lake ores, the following relations were obtained:

Gas retention time, sec	Lb of coke per net ton of iron
2.7	1800
2.9	1710
3.6	1727
3.5	1625
4.0	1620
4.3	1583
4.6	1523
5.2	1525

A straight line drawn through these points gives the relationship:

$$C = 2070 - 110\,T.$$

where C = lb of coke per net ton of iron.
T = retention time, sec.

Combining this relation with the previous formula for T, coke rate may be determined as follows:

$$C = 2070 - \frac{110 \times 185\ V}{L}$$

$$\text{or} = 2000\left(1 - \frac{10V}{L}\right)$$

Pig iron production may then be calculated by dividing the total daily coke consumption (L) by this coke rate:

$$P, \text{ net tons per day} = \frac{L}{C}$$

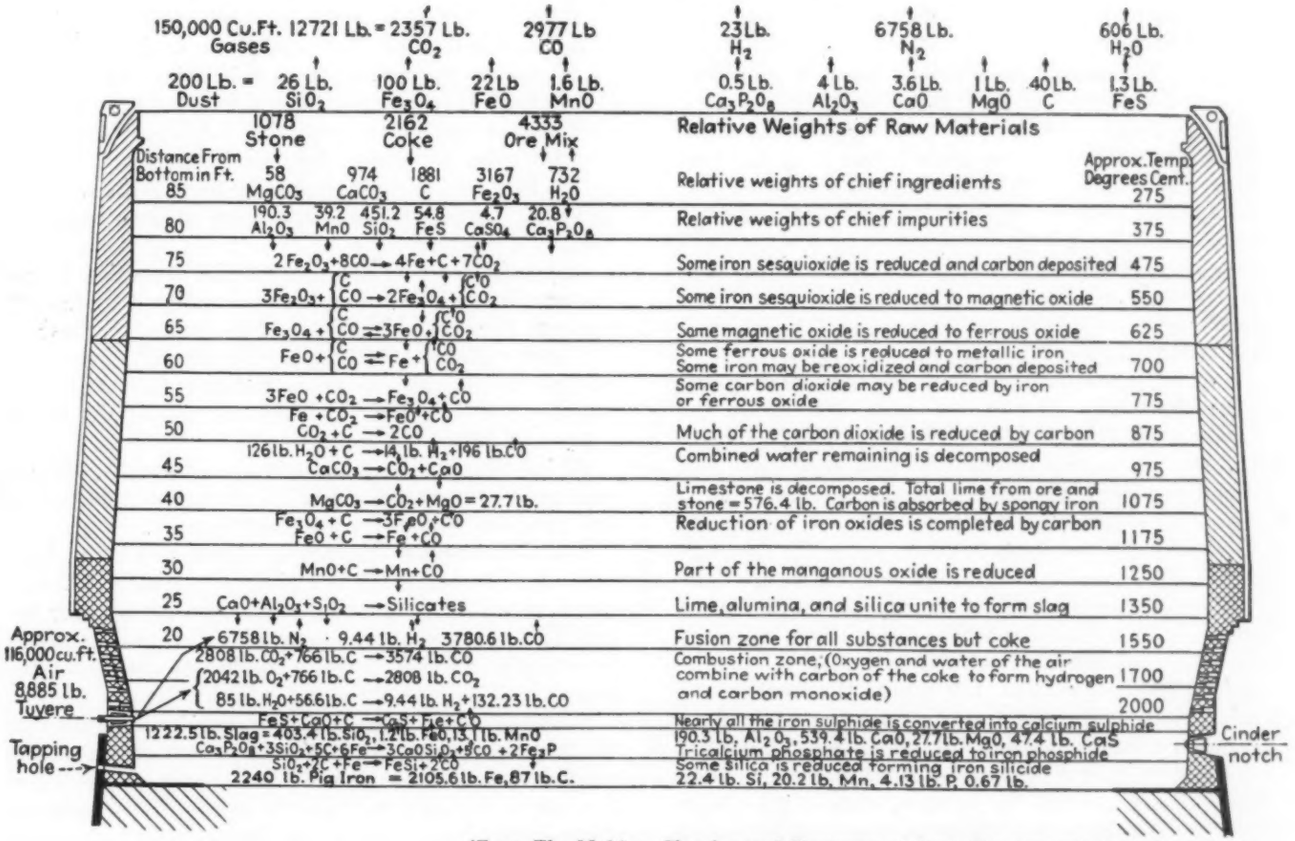
$$= \frac{L}{2000\ \left(1 - \frac{10V}{L}\right)}$$

The rate of production may be reduced to as low as 30 per cent of the normal rated capacity with satisfactory operation. Under such reduced rates of driving a higher blast temperature must be carried to insure hot iron. Chemical composition of the iron may be even more uniform than with normal production. Flue dust is greatly reduced. Consumption of cooling copper (or bronze) is reduced. The coke rate drops and CO_2 in the top gas (normally about 13 per cent) increases to about 16 per cent.

SMELTING PROCESS

The smelting of iron ore in the blast furnace is essentially a process of removing the oxygen from the iron oxides through the use of a reducing agent. Figure 33 gives typical conditions and reactions occurring in the furnace stock column. The average weight of the stock column is about 56 lb per cu ft and has 30-40 per cent voids. Tests of the composition of material from

Figure 33 — Chart showing smelting reactions in the stock column.


150,000 Cu.Ft. Gases 12721 Lb. = 2357 Lb. CO2 2977 Lb CO
200 Lb. = Dust 26 Lb. SiO2 100 Lb. Fe3O4 22 Lb FeO 1.6 Lb. MnO
23 Lb. H2 6758 Lb. N2 606 Lb. H2O
0.5 Lb. Ca3P2O8 4 Lb. Al2O3 3.6 Lb. CaO 1 Lb. MgO 40 Lb. C 1.3 Lb. FeS
1078 Stone 2162 Coke 4333 Ore Mix
Relative Weights of Raw Materials
Distance From Bottom in Ft.
58 MgCO3 974 CaCO3 1881 C 3167 Fe2O3 732 H2O
Relative weights of chief ingredients
Approx. Temp. Degrees Cent.
190.3 Al2O3 39.2 MnO 451.2 SiO2 54.8 FeS 4.7 CaSO4 20.8 Ca3P2O8
Relative weights of chief impurities
85
80
75 2Fe2O3+8CO → 4Fe+C+7CO2 Some iron sesquioxide is reduced and carbon deposited 475
70 3Fe2O3+ CO → 2Fe3O4+ CO2 Some iron sesquioxide is reduced to magnetic oxide 550
65 Fe3O4+ CO ⇌ 3FeO+ CO2 Some magnetic oxide is reduced to ferrous oxide 625
60 FeO+ CO ⇌ Fe+ CO2 Some ferrous oxide is reduced to metallic iron Some iron may be reoxidized and carbon deposited 700
55 3FeO +CO2 → Fe3O4+CO Some carbon dioxide may be reduced by iron or ferrous oxide 775
Fe +CO2 → FeO+CO
50 CO2+C → 2CO Much of the carbon dioxide is reduced by carbon 875
126 lb. H2O + C → 14 lb. H2+196 lb. CO Combined water remaining is decomposed
45 CaCO3 → CO2+CaO 975
40 MgCO3 → CO2+MgO = 27.7 lb. Limestone is decomposed. Total lime from ore and stone = 576.4 lb. Carbon is absorbed by spongy iron 1075
35 Fe3O4 + C → 3FeO+CO Reduction of iron oxides is completed by carbon
FeO + C → Fe+CO 1175
30 MnO+C → Mn+CO Part of the manganous oxide is reduced 1250
25 CaO+Al2O3+SiO2 → Silicates Lime, alumina, and silica unite to form slag 1350
20 6758 lb. N2 · 9.44 lb. H2 3780.6 lb. CO Fusion zone for all substances but coke 1550
Approx. 116,000 cu.ft. Air 8,885 lb. Tuyere
2808 lb. CO2+766 lb. C → 3574 lb. CO
2042 lb. O2+766 lb. C → 2808 lb. CO2
85 lb. H2O+56.6 lb. C → 9.44 lb. H2+132.23 lb. CO
Combustion zone, (Oxygen and water of the air combine with carbon of the coke to form hydrogen and carbon monoxide) 1700
2000
FeS+CaO+C → CaS+Fe+CO Nearly all the iron sulphide is converted into calcium sulphide
1222.5 lb. Slag = 403.4 lb. SiO2, 1.2 lb. FeO, 13.1 lb. MnO 190.3 lb. Al2O3, 539.4 lb. CaO, 27.7 lb. MgO, 47.4 lb. CaS
Ca3P2O8+3SiO2+5C+6Fe → 3CaOSiO2+5CO +2Fe2P Tricalcium phosphate is reduced to iron phosphide
SiO2+2C+Fe → FeSi+2CO Some silica is reduced forming iron silicide
2240 lb. Pig Iron = 2105.6 lb. Fe, 87 lb. C. 22.4 lb. Si, 20.2 lb. Mn, 4.13 lb. P, 0.67 lb.
Tapping hole
Cinder notch

(From The Making, Shaping and Treatment of Steel, The Carnegie Steel Co., 1925.)

TABLE XIII — TEST DATA FROM VARIOUS PLANES IN BLAST FURNACE STOCK COLUMN

	Tuyeres	24 ft above tuyeres	46 ft above tuyeres	57 ft above tuyeres	65 ft above tuyeres	Top
Per cent CO_2 in gas, by vol	0	5.5	12.0	15.0	14.8	14.6
Per cent CO in gas, by vol	32	34.5	27.7	25.3	25.0	24.7
Per cent H_2 in gas, by vol	1.5	1.0	2.3	3.2	3.4	4.1
Per cent N_2 in gas, by vol	66.5	59.0	58.0	56.8	56.5	56.6
Temperature, F	2,380	1,730	1,575	1,300	720	400
Pressure, in. Hg	30	23	13	10	4.7	3.9
Gas velocity, ft per sec	115	86	131	162	120	9
Cu ft of gas per sec, atmospheric conditions	960	1,085	1,075	1,120	1,090	1,110
Cu ft of gas per sec actual conditions	2,750	2,770	3,130	3,100	2,320	1,700
Cu ft of gas per sec per sq ft of area, actual	9.4	6.5	10.5	12.8	10.3	7.5
Gas flow, lb per min	4,470	5,200	5,300	5,450	5,400	5,450

various elevations in the blast furnace have been summarized as follows:

1. Results of sampling stock and gas in the upper part of the blast furnace stack show that 80-85 per cent of the iron in the burden has been reduced to metallic form by the time it has reached a point 19-20 ft above the tuyere level.
2. It has been shown that metal in the form of sponge iron, has taken up, or is intimately associated with, considerable quantities of carbon, sulphur, phosphorus, manganese and silicon by the time it has reached a point 19-20 ft above tuyere level.
3. About 87 per cent of the silicon entering the metal is taken up while the metal is in the bosh more than 2 ft above the tuyeres, and the remainder is taken up between this point and the crucible.
4. It has been shown that the silica in the coke ash has little effect on the amount of silicon in the metal, because the metal has obtained most of its silicon before it reaches tuyere level.
5. Approximately ⅓ of the manganese enters the metal or is very intimately associated with it by the time it reaches a point 19-20 ft above the tuyeres. The manganese content of 15 casts was 0.53 per cent; metal samples taken about 20 ft and about 2 ft above the tuyeres, contained 0.22 and 1.10 per cent respectively. Between these two points the metal takes up considerable manganese, part of which is probably oxidized later in the tuyere zone.
6. All of the phosphorus has entered the metal by the time the metal descends to about 2 ft above the tuyeres. Approximately ½ of the phosphorus has entered or become intimately combined with the metal at a point 19-20 ft above the tuyeres.
7. More than ⅓ of the carbon has been taken up by the metal by the time it reaches a point 19-20 ft above the tuyeres; the remainder is taken up while the metal is in the bosh of the furnace and before it reaches the level of the tuyeres.
8. The tolerant limit on sulphur is 0.05 per cent. At planes 19 ft, 2 ft, and 1 ft above the tuyeres the metal contained approximately 1.4,3.6, and 1.4 times, respectively, the tolerant limit. At 19 ft above the tuyeres, the metal had taken up 3.33 per cent of the sulphur charged into the furnace, while at 2 ft above the tuyeres the metal had taken up 12 per cent of the available sulphur. These results show the ease with which the metal has taken up sulphur in the upper part of the furnace; they also readily show that the metal continues to take up sulphur while it is in the bosh of the furnace, probably due to the fact that part of the metal is not covered by slag, and therefore subject to contamination with sulphur produced from combustion of coke at tuyere level.
9. Determination of forms of sulphur in coke samples at a plane 19 ft above the tuyeres shows that approximately 25 per cent of the sulphur has been removed from the coke by the time that it reaches this plane, and that the sulphur which has been removed is that which existed in the coke as ferrous sulphide and free sulphur. About ½ of the ferrous sulphide and free sulphur has been removed at this plane.
10. Analyses of samples of limestone taken from a plane about 19 ft above the tuyeres show that the lime has taken up 0.77 per cent sulphur, which is approximately 26.0 per cent of the available sulphur originally charged. Coke at this point has lost 25.0 per cent of its sulphur, and the metal has taken up 3.33 per cent of the available sulphur. Preferential absorption of sulphur by lime in the upper part of the furnace is demonstrated by these results.

Table XIII gives test data from various planes in the stock column.

Approximately 20 per cent of the reduction in the furnace occurs in the first 22 ft below the stock line, 75 per cent between this point and the top of the bosh.

Under ordinary conditions 50-75 per cent of the total manganese in the charge is reduced to metal. The charge should contain ⅔ - 1 per cent Mn to give about 1 per cent Mn in the iron.

Of the phosphorus present in the charge, 90-100 per cent enters the iron. Table XIV gives a sample burden and product balance for the blast furnace.

Conditions across the various planes may be far from uniform. Temperatures in a given plane may be 2 to 3 times as great in the center of the furnace as near the inwall. Gas analyses may vary widely across the plane, as may gas velocity. Typical conditions across various planes in a furnace are given in Table XV.

Such variations arise from conditions of charging and of material charged, and to some extent on the action within the furnace. The flow of stock in the blast furnace is not uniform. Directly above the tuyeres the stock settles faster than in the center. With an average rate of settling of 2 in. per minute, the rate near the walls has been measured at 2-⅔ in. per minute.

The effect of different variables in the charging of the furnace has been summarized as follows:

1. Size segregation in a furnace is due to the tendency of large particles to roll to the center. A greater coke-ore ratio usually occurs in the center of the furnace, due to the greater angle of repose of ore.
2. The average size of particles at the center may be decreased by decreasing the time of depositing materials on the bed. This may be done by —
   a. Keeping stock line close to bed.
   b. Increasing bell angle.
   c. Increasing speed and distance of bell drop.
   d. Increasing bell clearance.
3. The average size of particle at the center is increased by —
   a. Reversed filling — coke on the big bell first.
   b. Mixing — alternate skips of ore and coke.
   c. Decreasing size of ore charge.
   d. Decreasing bell clearance.
4. Unit charging — charging ore and coke separately — seems to have little effect.
5. About 12 per cent of extra water in the ore is undesirable for charging. Greater or lesser amounts of water than this have little effect on charging characteristics.
6. Furnaces operating on lake ores charge 30-40 per cent of the ore as potential flue dust (finer than 14 mesh) and ¼ to 1/6 of this is blown out.

SLAG

Blast furnace slags will usually fall within the following limits, depending on the nature of the raw materials used:

TABLE XIV — BURDEN AND PRODUCT BALANCE OF BLAST FURNACE

Analysis —

Charge	Element or radical	Per cent	Per cent of charge	Amount, lb per gross ton of iron
Ore mix	SiO_2	6.50	1.85	271.0
	Al_2O_3	2.40	0.67	100.0
	CaO	0.21	0.06	9.0
	MgO	0.23	0.07	10.0
	Mn	0.76	0.22	32.0
	Fe	50.50	14.34	2,106.0
	P	0.06	0.02	3.0
	O_2	24.90	7.07	1,039.0
	H_2O	14.44	4.10	600.0
Total		100.00	28.40	4,170.0
Coke	SiO_2	6.05	0.78	115.0
	Al_2O_3	3.00	0.39	57.0
	CaO	0.40	0.05	7.6
	MgO	0.18	0.02	3.4
	P	0.014	.....	0.3
	S	1.17	0.15	22.2
	C	89.186	11.53	1,694.5
Total		100.000	12.92	1,900.00
Stone	SiO_2	3.00	0.20	29.5
	Al_2O_3	1.20	0.08	11.8
	CaO	51.93	3.48	511.1
	MgO	1.15	0.08	11.3
	P	0.03	.....	0.3
	CO_2	42.69	2.86	421.0
Total		100.00	6.70	985.0
Air	O_2	23.00	11.75	1,720.0
	N_2	77.00	39.35	5,800.0
Total		100.00	51.10	7,520.0
Moisture in air and coke	H_2O	.....	0.88	130.0
Grand total		.....	100.00	14,705.0

Analysis —

Product	Element or radical	Per cent		Per cent of product	Amount, lb per gross ton of iron
Pig iron	Fe	94.00		14.33	2,106.0
	Mn	0.94		0.14	21.2
	Si	1.00		0.15	22.4
	P	0.14		0.02	3.1
	S	0.05		0.01	1.1
	C	3.87		0.59	86.2
Total		100.00		15.24	2,240.0
		By volume	By weight		
Slag	SiO_2	32.72		2.51	369.5
	Al_2O_3	15.02		1.15	170.0
	CaO	46.91		3.61	530.1
	MgO	2.17		0.17	24.5
	MnO	1.20		0.09	13.5
	S	1.98		0.15	22.4
Total		100.00		7.68	1,130.0
Gas	CO_2	14.8	21.5	15.67	2,317.0
	CO	25.6	24.0	17.50	2,589.0
	H_2	1.6	0.1	0.07	11.0
	N_2	58.0	54.4	39.63	5,800.0
Total		100.0	100.0	72.87	10,717.0
Moisture (in gas)	H_2O	32 grains per cu ft of gas		4.21	619.0
Grand total		.....		100.00	14,706

Note — This table does not account for flue dust, which means that amounts of solid materials entering the furnace are somewhat low.

	Per cent
SiO_2	30-38
Al_2O_3	11-15
CaO	33-48
MgO	2-17
FeO	Trace-1.0
MnO	Trace-2.0
K_2O, Na_2O	Trace-1.0
S	Trace-2.0
P	Trace

Although composed principally of silica, alumina, lime and magnesia as indicated above, blast furnace slag probably contains none of these substances as such, but rather various mineralogical compounds of the four, each having different characteristics. The melting point naturally varies with the character of the slag; 2500-2550 F represents an average melting temperature.

Increasing the basicity (CaO + MgO) of slag increases its melting point and also increases its attraction for silica and sulphur. A basic slag therefore reduces silicon and sulphur in the iron. This tendency, together with the tendency of high hearth temperature to lower sulphur and raise silicon affords control of these two elements, as illustrated by the following:

	Approximate per cent in iron	
	Si	S
Basic slag ($SiO_2 + Al_2O_3$ = 46-48 per cent), high hearth temperature	1.00	0.030
Neutral slag ($SiO_2 + Al_2O_3$ = about 50 per cent), high hearth temperature	1.50	0.045
Acid slag ($SiO_2 + Al_2O_3$ = 50-52 per cent), high hearth temperature	2.30	0.055

A decrease in the hearth temperatures in the above cases would lower the silicon and increase the sulphur in the iron.

Thus it may be seen that $SiO_2 + Al_2O_3$ makes up 46-52 per cent of the total slag, and these two substances are usually proportioned about 2.4 parts of SiO_2 to one part of Al_2O_3, or about 35 per cent SiO_2 and 14 per cent Al_2O_3. With less than 10 per cent Al_2O_3, difficulty may arise keeping the slag fluid unless it also contains about 40 per cent or more SiO_2 and is combined with a very high hearth temperature. On the other hand, about 15 per cent alumina in the slag is usually considered a maximum for good operation.

On the basic side of the slag, high MgO content is not desirable, acting to increase slag volume.

Slag volume must be within certain limits. If too low, the slag will not properly remove sulphur. Typical blast furnace slags will not ordinarily hold much over 2 per cent sulphur. Thus, if there is a deficiency of slag-forming material in the ore (less than about 6.5 per cent for usual conditions), silica is added in the form of lean silicious ores, mill cinder from heating furnaces, or sand.

On the other hand, an excessive slag volume slows production and increases coke consumption. With lake ores, slag volumes range from 950-1150 lb per net ton of iron. With southern ores, 1600-2300 lb of slag per net ton of iron may be obtained.

A suitable blast furnace slag should be "hot fluid and gray," flowing rapidly and quietly without froth or excessive viscosity.

Highly basic slag is usually light gray to bluish, with grainy fracture. High lime content tends to cause crumbling, which is retarded somewhat by magnesia. Slags containing over 50 per cent lime usually fall to powder upon cooling. As basicity decreases, slag shows a vitreous tendency, first around the outer edges, then glassy throughout.

Alumina gives a more earthy appearance than silica alone.

Under similar conditions slag from a cold furnace is more vitreous than from a hot furnace.

Silicious slags are more likely to carry iron oxide, which darkens the slag. Cold slags are more silicious than hot slags, hence cold slags are dark to black, and cloudy.

Aluminum silicate imparts a bluish color to slag, manganese a brownish color.

In addition to the oxide carried out of the furnace as

TABLE XV — CONDITIONS ACROSS VARIOUS PLANES IN BLAST FURNACE

Plane	Distance from center of furnace, per cent	Temperature of gases, F	CO_2 in gases, per cent	Velocity of gas, ft per sec	Static pressure, in. Hg
24 ft above tuyeres	0	1,940	5	170	24.0
	25	1,890	7	140	23.8
	50	1,810	10	100	23.6
	75	1,900	5	65	23.0
	100	1,700	2	110	22.0
46 ft above tuyeres	0	1,900	7	110	15.8
	25	1,780	11	105	15.4
	50	1,700	16	100	13.9
	75	1,400	19	90	12.9
	100	1,600	2	250	12.3
57 ft above tuyeres	0	1,750	13	320	12.0
	25	1,700	17	280	11.9
	50	1,650	19	220	11.7
	75	1,100	20	70	9.5
	100	1,500	8	180	8.0
65 ft above tuyeres	0	1,500	6	440	8.5
	25	1,350	18	220	7.8
	50	1,050	19	125	5.2
	75	700	17	110	4.2
	100	400	10	70	4.2

flue dust, about 0.15 per cent of the iron oxide charged is unreduced in normal blast furnace operation. Most of this goes into the slag and the remainder into the metal.

A cold furnace may produce slag containing up to 3.0 per cent FeO. A slag as strongly oxidizing as this is a poor desulphurizer, hence the increase in sulphur in the iron from a cold furnace.

COMBUSTION IN THE BLAST FURNACE

Various tests have shown that combustion in the blast furnace occurs in a space about 40 in. horizontally from the nose of the tuyeres and a similar distance above the tuyeres.

From 70 to 90 per cent of the carbon in the coke charged is burned at the tuyeres. The carbon used other than at the tuyeres may be divided as follows:

1. Reduction of silicon, manganese, phosphorus and sulphur. The metalloids are only reduced by solid carbon, and the carbon required is about 50 lb per ton of pig iron.
2. Reduction of the last trace of iron oxide. Iron oxide should be largely reduced by carbon monoxide, and indications are that at least 98 per cent of the ore is so reduced at temperatures below 1800 F.
3. Impregnation of pig iron. Solid carbon is absorbed by pig iron to the extent of about 4 per cent, or about 80 lb per net ton of pig iron.
4. Solution loss. The carbon dioxide in the gases passing up through the furnace causes solution loss of carbon before reaching the tuyeres. This loss increases with rate of driving, and is indicated by less air being used per lb of coke charged and a higher fuel consumption per ton of iron for a given rate of production.
5. Decomposition of water.

Carbon used other than at the tuyeres averages about 350 lb per ton of iron or about 20 per cent of normal coke consumption.

Carbon burnt at tuyeres may be calculated as follows:

$$\text{CO formed at tuyeres} = (0.5291 + 0.0038g)\ N_2$$

where CO = per cent by volume in gases at tuyeres.
g = grains of moisture per cu ft of air in blast.
N_2 = per cent by volume of nitrogen in top gas.

Weight of carbon burnt at tuyeres, lb per ton of iron, is given by the formula:

$$\frac{(0.5291 + 0.0038g)\ N_2}{CO_2 + CO + CH_4} \times C$$

where CO_2, CO, CH_4, and N_2 are per cent by volume of the respective gases in the top gas, C = lb of carbon gasified in furnace per ton of iron (= carbon charged in coke and in limestone, minus carbon in pig iron and in flue dust), and g= grains of moisture per cu ft of air in the blast.

If all the iron were reduced by CO according to the reaction:

$$Fe_2O_3 + 3\ CO = 2\ Fe + 3\ CO_2$$

the weight of carbon that would exist as CO_2 can be calculated, and equals 672 lb per ton of pig iron of 93.0 per cent iron. The actual weight of carbon as CO_2 in the top gases is calculated as given below:

$$\text{C as } CO_2 \text{ in top gases} = \frac{CO_2}{CO_2 + CO + CH_4} \times C$$

The difference between the actual weight and 672 represents solution loss.

The coke rate of a blast furnace depends on many conditions. A rough guide is as follows:

	Lb per net ton of iron
Basic iron, good ore	1600
Basic iron, poor ore	2000
Bessemer iron, good ore	1800
Bessemer iron, poor ore	2200
Foundry iron	2350
Spiegel iron	2500
Ferro-manganese	3600
Ferro-silicon	4000

Usual practice averages 2.7-2.95 lb of raw material smelted per lb of carbon in the coke. Hence, the carbon

TABLE XVI — HEAT BALANCE OF BLAST FURNACE

	Btu per lb coke	Btu per lb iron	Per cent
Input:			
1. Latent heat of coke	12,700	10,780	92.5
2 Total heat in blast	1,046	890	7.5
Total Input	13,746	11,670	100.0
Output:			
3. Latent heat in gas, gross	6,439	5,466	46.8
4. Sensible heat in dry gas	426	363	3.1
5. Total heat in moisture in gas	289	245	2.1
6. Sensible heat in iron	564	478	4.1
7. Sensible heat in slag	454	385	3.3
8. Dissociation of moisture	356	302	2.6
9. Reduction of iron oxides	3,260	2,763	23.7
10. Reduction of other oxides	234	198	1.7
11. Calcination of carbonates	369	315	2.7
12. Heat of carbon in iron	540	466	4.0
13. Radiation and unaccounted for	815	689	5.9
Total output (= input)	13,746	11,670	100.0

content of coke has a direct effect upon coke rate, as does the metallic content of the material in the furnace burden.

Rate of production also has an effect upon coke consumption. Experience has shown this effect to be somewhat as follows:

Production net tons of iron per day	Lb of coke per net ton of iron
932	1740
848	1695
690	1675
443	1625

Various factors which also influence coke consumption include pig iron and slag temperatures, blast temperature, moisture in the materials entering the furnace, slag volume, ash content of coke, solution loss in the stack, etc.

Temperatures prevailing in the smelting operation are somewhat as follows:

In crucible	2,750 F
At tuyeres	3,100 F
At furnace bosh	2,350 F
Furnace top	300 - 500 F
Gas temperature	300 - 500 F
Iron temperature	2,600 F
Slag temperature	2,650 F
Hot blast temperature	1,000 - 1,500 F
Flame temperature in stoves	2,200 F
Stove stack temperature	300 - 500 F

A typical heat balance of a blast furnace is given in Table XVI. The method of calculation is as follows:

Input:

1. Gross calorific value of one lb of coke.
2. Weight of dry air supplied per lb of coke × mean specific heat × temperature difference between blast and reference temperatures + weight of moisture carried by the air × its mean specific heat × temperature difference as above.

Output (= input):

3. Latent heat in gas = cu ft of gas produced per lb of coke × gross calorific value of gas per cu ft.
4. Sensible heat in dry gas = lb of dry gas produced per lb of coke × mean specific heat (about 0.245) × temperature difference between top gas and reference temperature.
5. Heat in moisture in gas = lb of moisture × [1,090.7 + 0.46 (temperature difference as in item 4)].
6. Heat content in iron = lb of iron produced by one lb of coke × heat content of one lb of molten iron (450-520 Btu per lb). Iron weighs about 450 lb per cu ft solid, 427 lb per cu ft molten.
7. Heat content in slag = lb of slag formed per lb of coke × heat content of one lb of fluid slag (750-900 Btu per lb). Slag weighs about 175 lb per cu ft.
8. Dissociation of moisture = total moisture carried into furnace by charge and blast per lb of coke used minus moisture carried out by gas from one lb of coke × 6800 Btu per lb.
9. Heat absorbed by reduction of iron oxides = lb of iron oxide reduced per lb of coke × 2,220 Btu per lb.
10. Heat absorbed by reduction of other oxides = lb of each oxide reduced per lb of coke × respective heats of reduction:

MnO	2,300 Btu per lb of oxide
SiO_2	5,700 Btu per lb of oxide
P_2O_5	4,730 Btu per lb of oxide

11. Calcination of carbonates = lb of limestone used per lb of coke × 0.95 × 800 Btu per lb.
12. Heat value of carbon entering iron = lb of iron produced per lb of coke × carbon content of iron × 14,540.
13. Radiation and unaccounted for, by difference, is usually 5-10 per cent. This also includes heat lost to cooling water, which can be separated out if the quantity of water and its average temperature rise are known.

BLAST FURNACE GAS

Gas from the top of a blast furnace may be regarded as having an analysis as follows:

	Per cent
$CO + CO_2$	39-40
H_2	2.0 - 2.5
CH_4	0.1
N_2	57.5 - 58.4

The hydrogen content is influenced by the water entering the furnace at or near the tuyere level — for example, as moisture in the blast or leakage from cooling devices. It has been shown that an addition of 4 grains of moisture per cu ft of blast increases the hydrogen content of the top gas 0.5 per cent. Methane (CH_4) is probably a result of volatile matter in the coke.

If the furnace burden should be unusually low in limestone (or other carbonate material) blast furnace gas will be unusually high in nitrogen. On the other hand, the introduction of oxygen without accompanying nitrogen will lower the nitrogen content of the gas. In average practice, however, the dry analysis is fairly consistent at about 58 per cent nitrogen. Since air contains 79.1 per cent nitrogen, each cu ft of blast therefore produces 79.1 ÷ 58 or 1.37 cu ft of gas.

Although CO + CO_2 in blast furnace gas is fairly constant at 39 per cent, the ratio of CO to CO_2 varies considerably, according to the coke rate of the furnace. Figure 34 shows this variation, as well as that of the heating value of the gas. Since the average coke rate for the country has dropped more than 300 lb per ton of iron in the past 30 years, gas quality has dropped over 5 Btu per cu ft in thermal value.

The amount of gas produced by the blast furnace per lb of coke charged depends on the percentage of carbon in coke and on the percentage of coke burned at the tuyeres, as shown in Table XVII. In northern practice, gas production averages about 71 cu ft per lb of coke (about 80.7 cu ft per lb of carbon) and blast requirements average about 52 cu ft of air per lb of coke (59 cu ft per lb of carbon). This corresponds to approximately 79 per cent of the charged coke burnt at the tuyeres.

In making Orsat analyses of blast furnace gas, the fact is often overlooked that the analyses obtained are for a theoretical dry gas. Actually, these gases never existed. As they come from the top of the furnace or

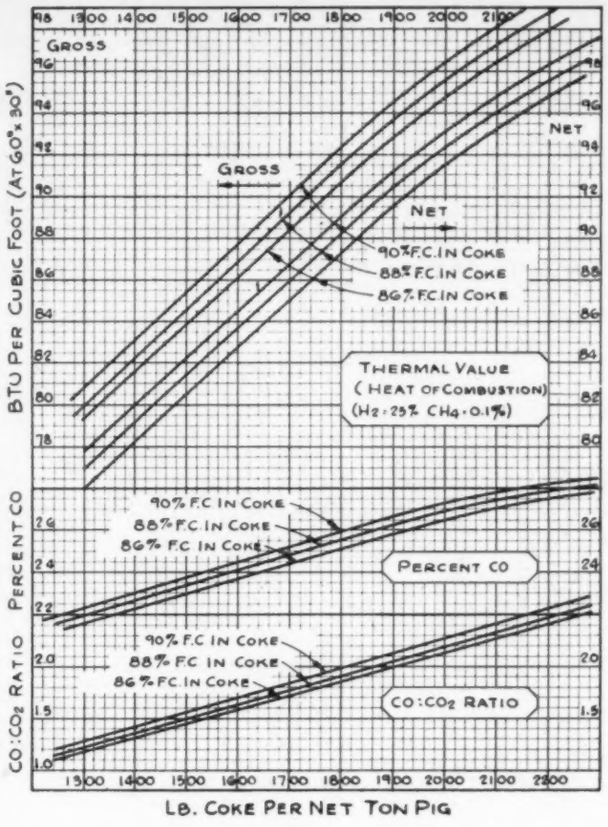


Figure 34 — Chart showing the characteristics of blast furnace gas with variations in coke quality and consumption.

from a wet-washer, or as they pass through the Orsat on a hot day, the gases may contain 30 grains of moisture per cu ft of dry gas, which will affect the true analyses somewhat as indicated below:

Per cent	Analysis of typical blast furnace gas	
	Theoretical	Actual
CO_2	13.3	12.22
CO	25.7	23.60
H_2	2.5	2.29
CH_4	0.1	.09
N_2	58.4	53.55
H_2O	.....	8.25
Btu per cu ft (gross)	92.0	84.0
Btu per cu ft (net)	90.7	83.3

The analysis of blast furnace gas in the Orsat is a wet analysis, giving readings of a moisture-saturated gas. Hence, correction factors (depending on the temperature of the analysis apparatus) should be applied to the burrette readings:

Temperature of apparatus, F	Multiply burrette Readings by
50	1.01
70	1.025
90	1.05
100	1.07
110	1.10

As previously indicated, one pound of coke produces about 71 cu ft of blast furnace gas in normal practice. Of this, the hot blast stoves may consume 20-25 per cent, and leakage may account for several per cent. Hence, about three-quarters of the gas is surplus, and may be used for underfiring coke ovens, steam generation or metallurgical heating.

Credit is usually allowed the blast furnace for the excess gas produced. The method of determining this credit differs in the various plants. In some few cases the gas is actually measured, but more often it is calculated by means of a carbon balance, or from the fuel it replaced. The gas is usually evaluated according to the fuel it replaces. Care must be taken in establishing such credits so that no department concerned is unfairly penalized.

The *carbon balance* is made as follows:

$$\frac{Cc + Cs - Ci - Cd}{Cg} = V$$

where Cc = wt of carbon in coke per ton of iron.
Cs = wt of carbon in stone per ton of iron.
Ci = wt of carbon in pig iron (one ton).
Cd = wt of carbon in flue dust per ton of iron.
Cg = wt of carbon in cu ft of blast furnace gas.
V = cu ft of gas made per ton of iron.

This can best be illustrated by an example:

Net tons of iron produced per day	822
Lb of coke per net ton of iron	1590
Lb of stone per net ton of iron	840
Gas analysis:	
CO_2	13.4 per cent
CO	26.9 per cent
H_2	2.1 per cent
N_2	57.6 per cent
Btu per cu ft (gross)	93.9
Carbon in coke	87.5 per cent
Btu per lb of coke	12,450
Flue dust made, lb per gross ton of iron	178

TABLE XVII — CU FT OF BLAST FURNACE GAS PER LB OF COKE CHARGED

Per cent of coke burnt at tuyeres	Per cent fixed carbon in coke			
	84	86	88	90
78	66.8	68.3	69.9	71.5
79	67.6	69.3	70.8	72.4
80	68.4	70.1	71.7	73.3
81	69.2	70.8	72.4	74.1
82	69.5	72.0	73.6	75.2

$Cc = 0.875 \times 1590 = 1395$ lb.

$Cs = 840 \times 0.42 \times 3/11 = 96$ lb
(Stone is 42 per cent CO_2).

$Cg = (0.134 + 0.269) \times 0.0316 = 0.0127$ lb.
(0.0316 is a constant, denoting the weight of carbon in a cu ft of any gas, under standard conditions, in which there is one atom of carbon per molecule.)

Ci = about 3.8 per cent = 76 lb.

Flue dust may contain 8.0-20.0 per cent carbon. Say 0.10×178 equals 18 lb of carbon in flue dust.

Then,

$$V = \frac{1395 + 96 - 76 - 18}{0.0127} = 110{,}000 \text{ cu ft per net ton of iron.}$$

$\frac{110{,}000}{1590} = 69.2$ cu ft of gas per lb of coke. Cu ft of air blown per ton of iron is determined by the ratio of nitrogen in the gas to nitrogen in the air, and equals

$$110{,}000 \times \frac{0.576}{0.79} = 80{,}000.$$

$\frac{80{,}000}{1590} = 50.3$ cu ft of air per lb of coke.

Latent heat in gas $= 69.2 \times 93.9$.
$= 6{,}510$ Btu per lb of coke.

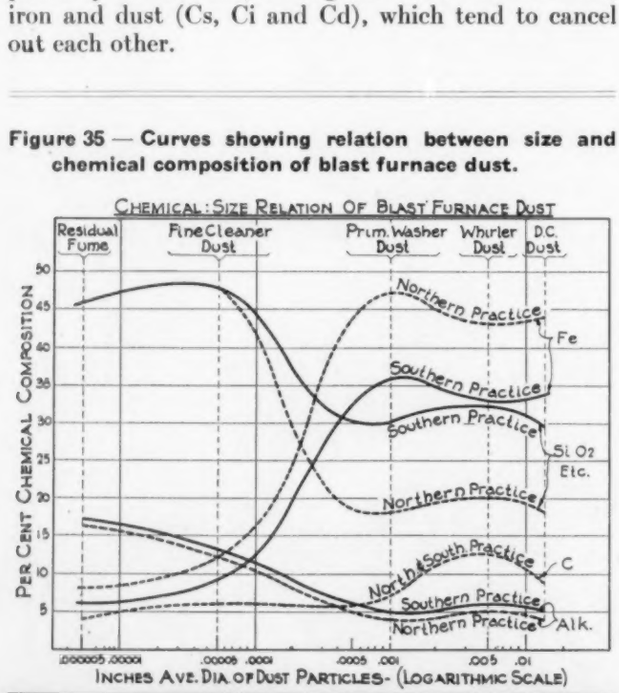
$\frac{6{,}510}{12{,}450} = 52.2$ per cent of heat of coke appears in the gas.

Blast furnace calculations of this type should be based on monthly averages; daily figures are not reliable.

Checking calculations of the type shown above against actual measurements, the Bureau of Mines (Technical paper No. 401) found variations of less than 1.5 per cent.

It is somewhat simpler (and in average practice, probably as accurate) to neglect carbon in the stone, iron and dust (Cs, Ci and Cd), which tend to cancel out each other.

Figure 35 — Curves showing relation between size and chemical composition of blast furnace dust.



GAS CONDITIONING

As blast furnace gas leaves the top of the furnace, it carries a dust content of perhaps 4-20 grains, per standard cu ft; 10 or 12 grains per cu ft might be a fair average (5.6 grains per cu ft = 100 lb of flue dust per ton of iron). Other conditions being equal, the amount of dust depends on the gas velocity at the stockline of the furnace. This dust covers an extremely wide size range, running from about one-tenth of an inch down to two-millionths of an inch in diameter. It is composed of iron ore, coke and some alkalies, with the composition varying with the size of particles somewhat as shown in Figure 35.

In addition to the dust content, blast furnace gas also carries between 7 and 50 grains of water vapor per cu ft, averaging perhaps 25 in northern practice and 34 in southern practice.

The removal of dust is essential to avoid fouling up the gas mains and the gas-consuming equipment, as well as to improve combustion characteristics. The reduction of moisture content is likewise desirable from a combustion standpoint.

The degree to which blast furnace gas should be cleaned depends upon the use to which it is to be put. For modern, small-checker stoves, present practice favors reducing the dust content of the gas to 0.015-0.025 grains per cu ft. In stoves having checkers of 3 in. or more, a dust content of 0.10-0.15 grains per cu ft seems to be satisfactory if entrained moisture is low. Boilers, soaking pits and heating furnaces operate satisfactorily on gas cleaned to 0.10 grains per cu ft or less if it is also free from entrained water. Some boiler plant experience has shown deposits from wet-washed blast furnace gas, even though cleaned to 0.06 grains per cu ft, are very difficult to remove in service. Some operators therefore feel that, unless wet washing is followed by precipitator cleaning to 0.02 grains per cu ft. dry cleaning is preferable. There will be deposits on boiler tubes, whether gas carries 5 or 0.05 grains per cu. ft. However, deposits from dry cleaned gas do not bake on to the tubes, while deposits from wet-washed gas are of finer texture and cling to the tube surfaces. It is felt in some quarters that gas of 2 grains per cu ft dust content will perform satisfactorily in boilers equipped to handle the dust as powdered coal fly ash.

For heating coke ovens and for gas engines, cleaning to 0.01 grains per cu ft or less seems to be essential.

The *dust catcher* is fundamentally a settling chamber, wherein dust is dropped out of the gas by reducing the velocity of gas flow. The shell is usually at least 30 ft in diameter, and the gas stream makes a U-turn while its velocity is reduced to perhaps one-tenth of the entering velocity. Figure 36 shows a typical dust catcher with a single large entry pipe in the top leading down part way inside the chamber portion, and a concentric offtake at the top. Another recent design uses a gradually flaring pipe within the shell. This unit uses a 9 ft diameter inlet, giving a gas velocity of about 50 fps in the header entering the shell, while the flaring entry pipe reduces this velocity to 9.6 fps. The velocity up through the annular ring around the entry pipe is 4.8 fps. The shell of this unit is 35 ft in diameter and 37 ft

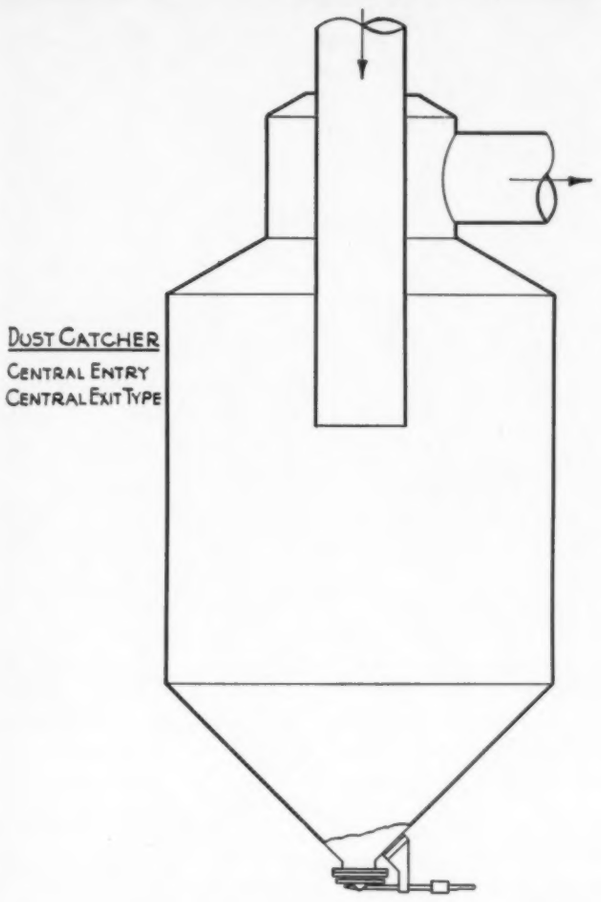


Figure 36 — Sketch showing general arrangement of dust catcher (central entry, central exit type). ↑

Figure 37 — Cross section of wet washer with electrostatic precipitator located on top. →

on the straight side wall. The velocity in the exit pipe is 65 fps.

A good dust catcher may clean gas down to 3 grains per cu ft if the entering gas is not too dirty. Efficiencies may range 50-80 per cent. If the unit is small for the gas volume passing through, the efficiency may drop as low as 30 per cent.

Pressure loss through the dust catcher is 0.5-1.0 in. of water.

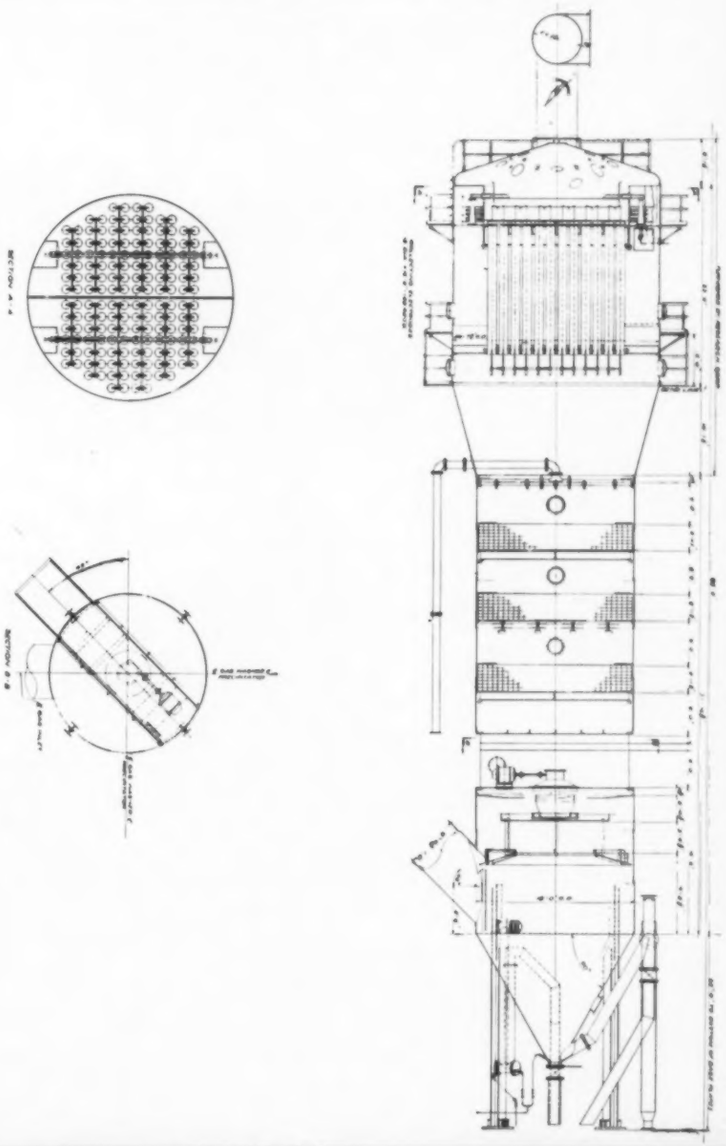
Inasmuch as 50-300 lb of dust may remain in the dust catcher for each ton of iron produced, it is desirable to install a pug mill under the dust catcher. This provides a convenient means of handling the dust and eliminates a dirty spot in the plant.

In some cases a *whirler* or some similar secondary rough cleaner follows the dust catcher. Such units are usually of small diameter and considerable height, and employ centrifugal force to throw out dust. A good whirler will clean gas down to about 2 grains per cu ft. Although many of these units have been installed, present thinking holds them unnecessary unless the primary dust catcher is inadequate or unless a subsequent primary washer requires cleaner gas than the dust catcher will normally provide.

In general, *primary wet washers* now consist of a cylindrical steel tower containing hurdles, baffles and water sprays in many different combinations and arrangements. Low-head recirculating pump units in the form of rotors may also be used in the bottom of the washer to create more intimate contact between gas and water. Designs are such as to employ some of the following principles:

1. Subdivision of gas into small streams.
2. Turbulence of flow of gas streams.
3. Contact of gas with extended wetted areas.
4. Wetting by water vapor condensation.

Modern designs of primary washers can clean gas down to a dust content of 0.05-0.15 grains per cu ft, although the older units seldom get below about 0.25 grains per cu ft. Water consumption is approximately 25 or 30 gal per 1000 cu ft of gas; although recirculation of water as used in the design of Figure 38 cuts this consumption to about 20 gal per 1000 cu ft of gas, although circulation is approximately 40 gal per 1000 cu ft of gas. Gas pressure loss through primary washers runs 10-15 in. water column.



Gas which has been through a primary washer carries a considerable quantity of entrained moisture. Such gas results in many unfavorable conditions when it is burned in boilers or stoves. To eliminate the entrained moisture, various devices have been tried. One successful modern design consists of a group of parallel concentric gas passages, relatively narrow and relatively high, whose walls consist of steel plates coated on both sides with vulcanized rubber. The unit is installed either in the gas main after the washer or on the top of the primary washer. Moisture eliminators improve the efficiency of primary washers and results in great improvement in the condition of the exit gas.

The rotating *disintegrator* consists of a rotor carrying perforated spray cones and concentric rows of stainless steel bars arranged parallel to the axis of rotation, operating between two stationary baskets of similar construction. Water is injected to the center of the perforated cones and distributed by centrifugal force over the rotary and stationary baskets, where it is atomized into mist which wets down the dust. Through the addition of fan blades on the rotor, gas pressure can be boosted as much as 16 in. of water column.

Disintegrators are customarily used in capacities of 45,000 cfm of gas. Water requirements range 4-8 gal per 1000 cu ft of gas, and power requirements 4-10 kw per 1000 cfm or 0.07-0.17 kwhr per 1000 cu ft, depending on the degree of cleanliness required and the amount of the pressure increase.

Disintegrators are capable of cleaning blast furnace gas to 0.005-0.020 grains of dust per cu ft, with the results seemingly independent of whether the entering gas carries 0.10 or 0.30 grains per cu ft.

The *electrical precipitator* (Figure 39) has been widely used for final gas cleaning in many modern furnace plants. It is based on the principle that if suspended particles are placed in a high voltage electrical field, they receive an electric charge and will move toward one or the other of the electrodes supplying the field. As used in these units, one electrode is a vertical pipe with a smooth interior and the other is a wire axially suspended in the center of the pipe. As the field is strongest around the wire and weakest near the pipe, the charged dust particles collect on the walls of the pipe, and are then washed away by a film of water flowing down the pipe surface.

Recent precipitator units contain 208-224 vertical pipes, 15 ft long and 8 or 12 in. in diameter. A square wire (about ¼ in.), twisted one turn in 8 or 10 in. is placed along the axis of each tube. The cylindrical shell housing this assembly may be divided into two equal sections by a partition, so that one side may be shut down for repairs while the other side continues to operate.

Electrical equipment consists of a single phase, high voltage transformer to raise alternating current at usual plant voltage up to 50,000-75,000 volts. Mechanical rectifiers then change this high voltage a-c power to unidirectional power. One side of the rectifier is grounded, as are the precipitator pipes, while the other side is connected to the wires which are suspended in the pipes and carefully insulated from them.

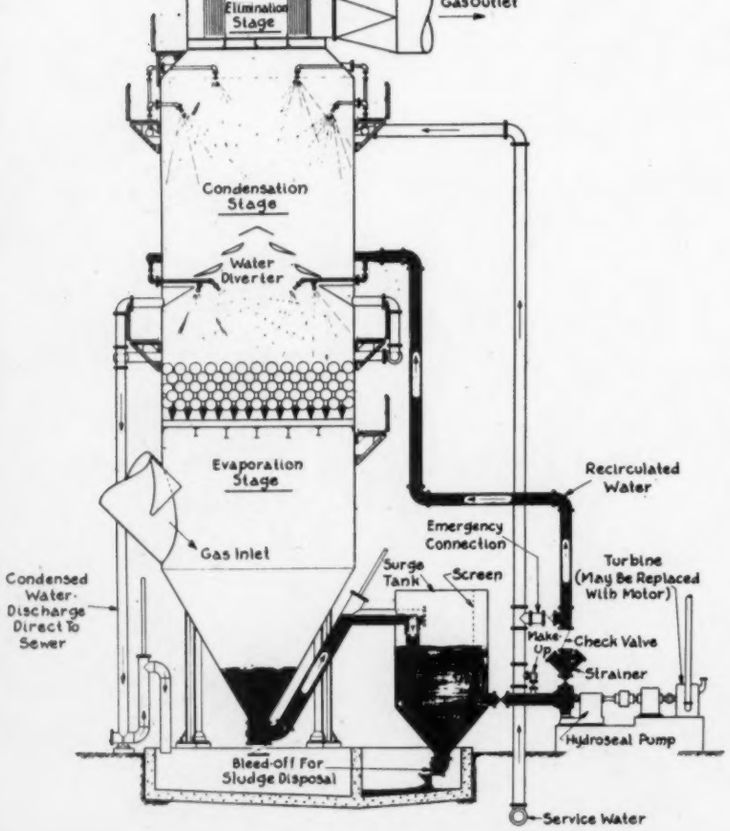
The capacity of a precipitator depends definitely upon the dust content of the incoming gas and the required cleanliness of the exit gas. For example, with incoming gas of 0.25 grains per cu ft dust content, an 8 in. × 15 ft tube will clean about 220 cfm to a final dust content of 0.010 grains per cu ft or 350 cfm to a final content of 0.025 grains per cu ft, or with an initial gas of 0.10 grains per cu ft dust content, it will clean 310 cfm to 0.010 grains per cu ft and 450 cfm to 0.025 grains per cu ft or less. A rate of 450 cfm (representing a gas velocity of about 22 fps) is the maximum limit for an 8 in. tube. Otherwise the dust particles are not able to reach the tube wall before they are carried through the tube.

Power input to a precipitator is about 0.2 kw per 1000 cfm, which means a power consumption of about 3 kwhr per million cu ft of gas. Some plants report a power consumption as low as 1.5 kwhr per million cu ft of gas. Water consumption is about 2.2 gal per 1000 cu ft of gas, and steam consumption (used to keep insulators clean and dry) amounts to about 100 lb per hr.

One design places an electrical precipitator on top of a hurdle washer. The washer is 18 ft in diameter × 52 ft high and contains a rotor element immediately above the gas inlet, topped by three 3 ft banks of drip tile and 26 spray nozzles. The precipitator contains 168 tubes 12 in. in diameter × 15 ft long. A unit of this type will clean 70,000 cfm of blast furnace gas to a final dust content of 0.006-010 grains per cu ft.

Several fine *dry cleaners* have been developed but none

Figure 38 — Gas conditioner, with no moving parts, based on condensation-wetting principle. About half of the water requirement is recirculated.



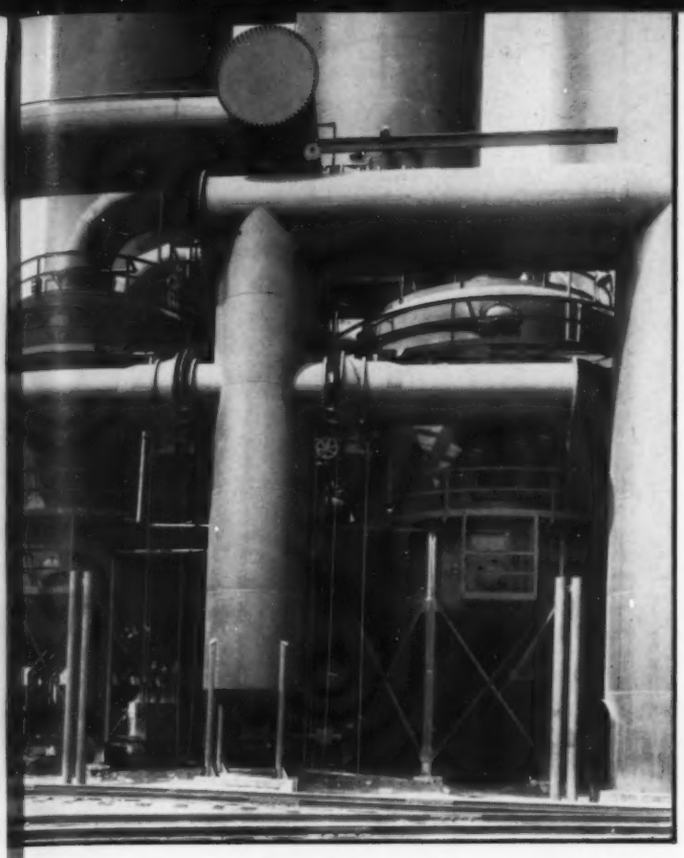


Figure 39 — The electrical precipitator has been widely applied for fine gas cleaning in modern furnace plants.

are in wide use in the United States. Several dry-type electrical precipitators are still in use, but these units clean down to only 0.15 grains per cu ft, even with two units in series. Another design, used in Germany but not in the United States, is the bag filter system, which will clean gas of 2 grains per cu ft down to 0.002 grains, for an efficiency of 99.9 per cent. The units are costly and cumbersome, and the temperature of the gas passing through must be carefully kept between definite limits.

Table XVIII shows typical performance of the various cleaning units. As installed in recent blast furnace plants, gas cleaning equipment usually consists of a dust catcher, a primary washer and an electrical precipitator.

SLUDGE RECOVERY

The water leaving a wet gas washer carries 120-200 grains of solids per gallon, or 20-50 tons of solids per day from the typical furnace. Containing 50 to 60 per cent of iron ore, this sludge is of sufficient value to economically warrant its recovery. Furthermore, there are few locations where the water from a gas washer can be disposed of without clarification.

In modern plants, the most widely used equipment for sludge recovery is the thickener consisting of a steel or concrete tank 40-80 ft in diameter, about 6 ft deep, and having a centrally depressed conical bottom. Water from the gas washer is brought in a trough to the center of the tank, from where it disperses radially in all directions with ever-decreasing velocity. Around the outer edge of the tank is a level weir over which the clarified water flows into a collecting trough (see Figure 40).

Solid material settles to the bottom of the tank and is plowed to the low center point by radial sweeps rotating at a peripheral speed of about 25 fpm. Sludge, containing about 50 per cent water, passes through an outlet in the tank bottom, and to a diaphragm pump which delivers the sludge to a filter. The final filter cake contains 18-25 per cent water, and can be satisfactorily

Figure 40 — Sludge from wet washers is usually reclaimed by settling in a thickener.

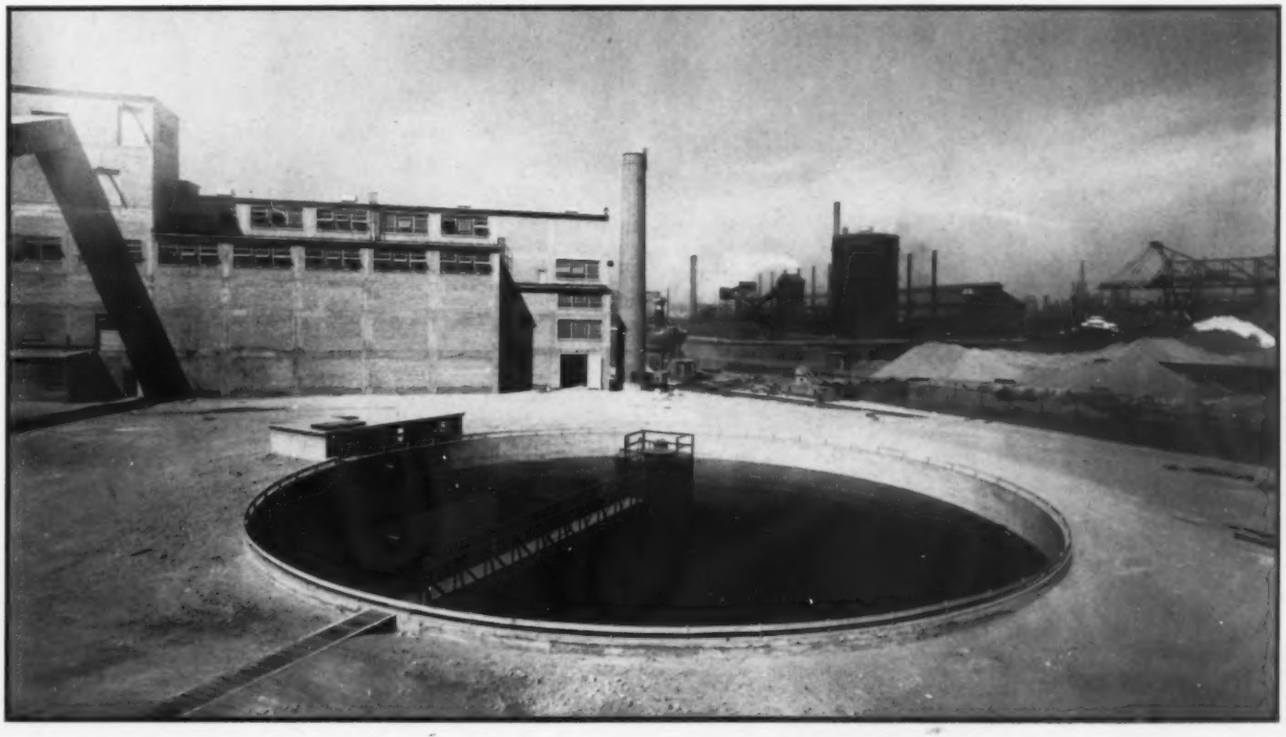


TABLE XVIII — TYPICAL GAS CLEANING PRACTICE

Type of apparatus	Capacity cfm	Dust contents grains per cu ft		Efficiency per cent	Moisture content, grains per cu ft		Temperature, F		Pressure change through cleaners, in. H-O	Kwhr per 1000 cu ft of gas	Water gal per 1000 cu ft of gas
		Entering	Leaving		Entering	Leaving	Entering	Leaving			
Dust catcher	Up to 120,000	4-20	2-10	50-75	7-50	7-50	250-450	250-450	0.5-1.0 loss	.....	.....
Whirler	Up to 120,000	3-10	2-7	50-70	7-50	7-50	200-400	200-400	1.0-3.0 loss	.....	.....
Primary washer, with moisture eliminator	Up to 120,000	2-10	0.1-1.0	80-95	7-50	5-15	200-400	70-100	5-15 loss	.....	25-35
Disintegrator	45,000	0.1-1.0	0.005-0.020	95-98	6-15	5-13	70-100	55-85	3-16 gain	0.07-0.17	4-10
Electrical precipitator	40,000-90,000	0.1-1.0	0.005-0.020	92-99	6-15	6-15	60-100	55-95	1-3 loss	0.003	2-3

mixed with other materials for sintering. The clarified water still contains 10-20 grains of suspended solids per gal.

The capacity of a thickener depends on the degree of clarification desired:

Solids left in water, grains per gal	Capacity, gal per day per sq ft of area	
	Primary washer water only	Including secondary cleaner water
5	700	450
10	900	600
15	1100	800
20	1260	960
25	1400	1100
30	1520	1230

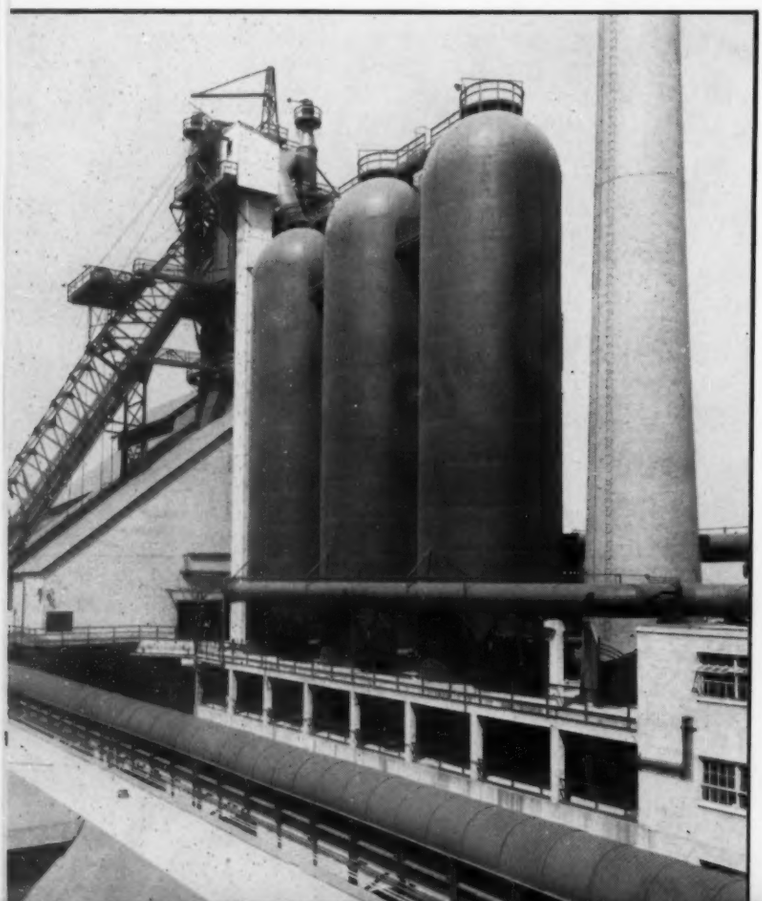


Figure 41 — Regenerative hot blast stoves, 20-26 ft in diameter and 90-115 ft high, heat the blast for the ← furnace.

STOVES

Blast for the furnace is heated in regenerative hot-blast stoves (Figure 41) ranging 20-26 ft in diameter and 90-115 ft high. Stove shells are made of $\frac{5}{8}$ or $\frac{3}{4}$ in. plates, with both vertical and horizontal joints welded or double riveted.

Within the shell of the modern stove, the design is such as to give a two-pass construction. The first pass is really a combustion chamber of circular or elliptical cross-section which rises vertically from the stove burner at the bottom up to the top dome. The cross-sectional area of the combustion chamber depends on the rate at which gas is to be burned in the stove. A gas-burning rate of 400 cfm per sq ft of area is generally considered a maximum for pulsation-free combustion, although rates of 600 cfm per sq ft have been used without trouble. A low back-pressure in the combustion chamber aids in preventing burner pulsation, as do a flared burner connection, a large burner opening into the combustion chamber, and a high-head fan for combustion air. Many large modern stoves, however, are designed with gas-burning rates of 300-325 per sq ft of combustion chamber cross-sectional area.

The combustion chamber is usually placed along one side wall of the stove, although there are also many center-combustion stoves in existence. The second pass of the stove is filled with checkerwork, which provides the principal heating surface. Checkerwork was formerly of straight checker flue design, formed by straight brick shapes, but as furnace design increased (and as cleaner gas permitted), smaller checker openings and thinner refractory walls became prevalent, thus increasing stove efficiency while at the same time reducing stove size.

Blast temperatures usually run 1000-1500 F. In this range the heat content of air is about 0.02 Btu per cu ft per degree F. Figure 43 gives total heat content of air at various temperatures. This heat must be absorb-

ed from the checkerwork in the stoves. At the prevailing brick temperatures existing in stoves, the mean heat capacity of fireclay brick is about 0.28 Btu per lb per degree F.

In normal operation, the mean temperature drop permissible in the stove brickwork during the blast period may run 400-600 degrees, depending on the blast temperature carried. Then:

$$W = \frac{H \times t \times V \times f}{0.28 \times d}$$

Where W = weight of effective brickwork, lb.
H = Btu content of one cu ft of air at blast temperature.
t = period the stove is to remain on blast, min.
V = blast volume, cfm.
f = a factor to provide reserve capacity (= 1.15 in typical cases).
d = mean temperature drop in brickwork, degrees F.

Effective brickwork is defined as the volume within about ¾ in., of a heating surface, so that the mass is close enough to an exposed surface to allow stored heat to reach the surface before the surface temperature falls below the required point. This, of course, varies with the design of the checkerwork. Ordinary basket-weave checkers, consisting of openings 2½-4 in. square formed by bricks 2-3 in. thick, may have only 50-75 per cent of its total brick mass within this "effective" range. Patented checker tile, however, may place as much as 95 or 96 per cent of its brick mass within the effective limits.

From the foregoing, the actual mass of checkerwork required may be calculated, and using the average value of 75-80 lb of actual brickwork per cu ft of checkerwork volume, the volume of checker space can be estimated. In practice, individual stoves are found to contain 0.28-0.45 cu ft of checker space per cfm of blast, with modern units inclining to the lower side.

Further, it is usually found that checkerwork occupies 40-50 per cent of the total shell volume. Hence, shell dimensions may be determined, keeping in mind the general proportions previously given.

In modern stove design, a straight line blast temperature of 1500 F is often specified, which means a heat content of 28 Btu per cu ft of air. A blast period of 90 min is also widely used, with an average temperature drop of 425-450 degrees. On this basis, 21-24 lb of effective brick mass is needed in each stove per cfm of blast. Since effective brick mass is taken as that within ¾ in. of a heating surface, each sq ft of heating surface should be backed up by 12 × 12 × 0.75 cu in. of brick, or about 8.1 lb, which, coupled to the mass figure above, would give an effective heating surface of 2.5-3.0 sq ft per cfm of blast.

Although not a definite measure of stove capacity, the heating surface provided by the checkerwork is nevertheless important, as the transfer of heat into and

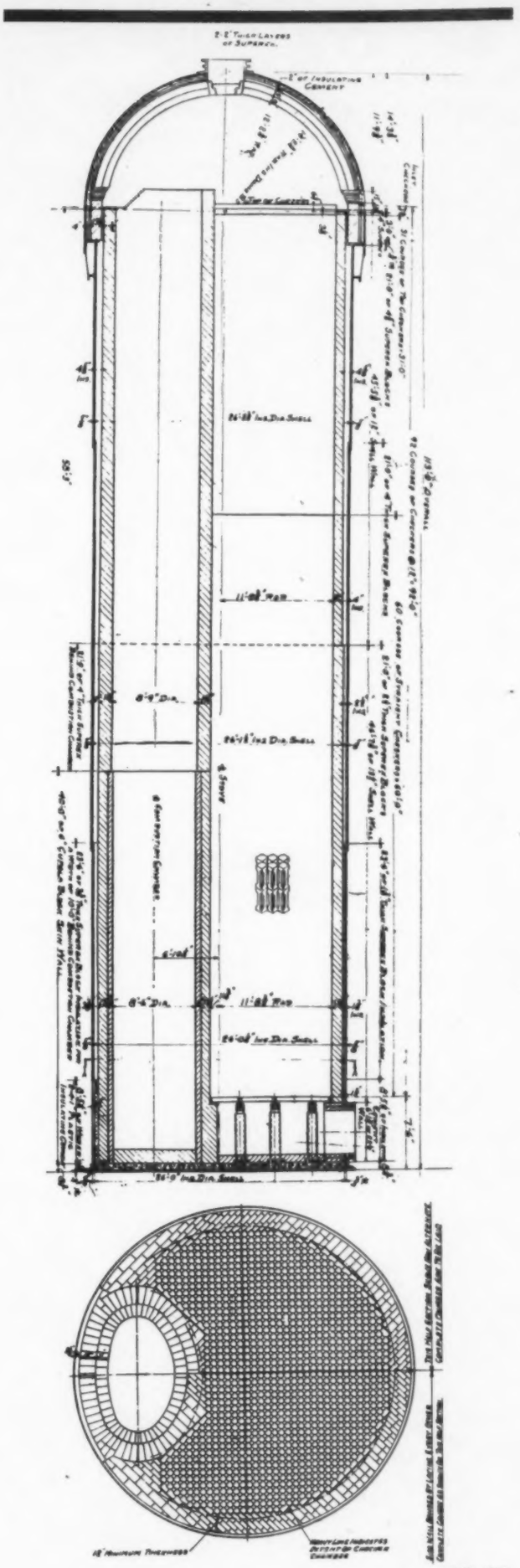


Figure 42 — Sections of a typical stove. →

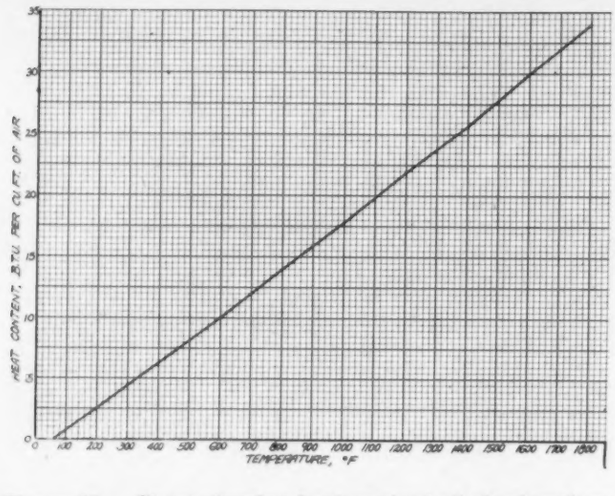


Figure 43 — Chart showing heat content of air at various temperatures.

out of the brick is essentially a surface action. The surface offered by a given volume of checkerwork varies with the design, and may range from 5 to 9 sq ft of effective surface per cu ft of checkerwork volume, modern designs usually showing 8 to 9. Only surface which is swept by gas flow is effective. Tests on modern hot blast stoves have shown average heat transfer rates of 5-11 Btu per sq ft per min during the blast period and 8-15 Btu per sq ft per min during the gas period, although values probably average under 10 for each period in conventional stove practice.

Table XIX gives some design figures evidenced in existing stove installations.

From the preceding, it is seen that the size of an individual stove depends on its ability to give up to the blast a sufficient quantity of heat for the desired period of time. The number of stoves, however must be based on rate at which the stove may be reheated during the gas period. Since the heat transfer rates during the gas period may exceed those during the blast period, as given above, it is theoretically possible to operate with only two stoves. There are bound to be periods, however, when lean gas or similar difficulties may prevent the stove on gas from absorbing heat at a higher rate than it gives up heat while on blast. Further, time for stove changing must be allowed, which may average 15 or 20 min. Thus, with a blast period of 90 min, the gas period could be only 75 min with two-stove operation. Also, there are occasions when a stove must be taken out of service for maintenance. Three stoves are therefore the minimum installed for a furnace, and if of proper size with adequate combustion capacity, three stoves are sufficient. Should it be necessary to use existing small stoves in connection with a large furnace, four stoves may be required or in extreme cases, even five, although, in general, four or more stoves are an inheritance from the days of dirty gas, with frequent shutdowns for cleaning.

Modern installations (see Table XX) are usually of three stoves, totaling 7-8 sq ft of heating surface per cfm of blast, or 425-500 sq ft per ton of daily iron capacity.

When it becomes necessary that one stove be taken out of service in a three-stove installation, operation is

TABLE XIX — DESIGN CHARACTERISTICS OF HOT BLAST STOVES

	Range	Modern designs
Per cfm of blast		
Cu ft of checker space, each stove	0.28-0.45	0.28
Lb of brick mass, each stove	21-33	22.
Sq ft of effective heating surface, each stove	2.5-3.0	2.55
Sq ft of heating surface, all stoves	6-9	7.6
Sq ft of heating surface (all stoves) per ton of daily iron capacity	400-500	450-500
Sq ft of effective heating surface per cu ft of checker space	5-10	8.7
Sq ft of effective heating surface per cu ft of brick volume	8.5-17.0	15.1
Lb of actual brick mass per cu ft of checker space	75-80	78
Portion of brick mass that is effective, per cent	50-96	95-96
Cu ft of brick volume per sq ft of heating surface	0.055-0.10	0-064
Lb of brick per sq ft of heating surface	7.2-13.5	9
Ratio, brick volume to checker space, per cent	56-66	57.5
Ratio, checker space to shell volume, per cent	40-50	46
Free area through checkerwork, per cent	35-45	40
Average velocity of gas in checkers, ft per sec	5-8	.....

TABLE XX — TYPICAL STOVE INSTALLATIONS

Furnace hearth diameter	18′-6″	22′-0″	25′-0″	25′-6″	27′-0″	27′-0″
Number of stoves	4	3	3	3	4	3
Shell size, ft	24 ×110	22 ×100	24 ×100	25 ×115	22 ×100	25 ×114
Total heating surface sq ft (all stoves)	548,000	370,230	573,000	630,000	380,000	630,000
Type of checkers	Special tile	2 9/16″ flue openings, 1 11/16″ wall thickness	1 5/16″ flue openings, 1¼″ wall thickness	.....	3½″ flue openings, 2″ and 2½″ wall thickness	2″ flues
Type of gas burner	Pressure	Pressure	Pressure	Pressure	Pressure	Pressure
Automatic mixer control	Yes	Yes	Yes	Yes	Yes	Yes

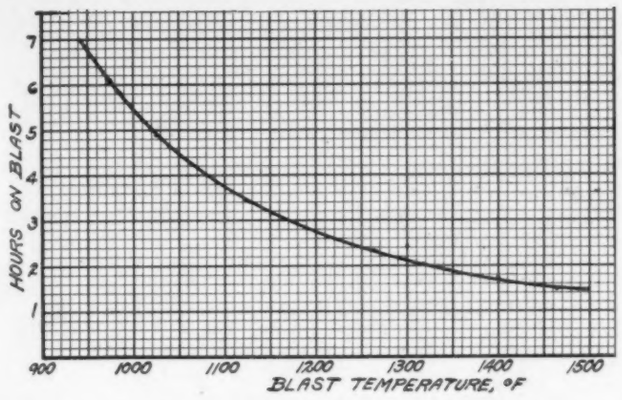


Figure 44 — Curve from test data, showing variation of blast periods with varying blast temperature. These periods lasted until the mixer valve closed.

not severely penalized, inasmuch as modern stoves are usually predicated on a 1500 F blast temperature, while the furnace operates at perhaps 1200 F. Figure 44 shows how blast periods vary with blast temperature for a given stove. These periods lasted until the mixer valve closed.

Gas burners for stoves are now generally of the pressure type, designed to proportion gas and air. Their capacity must be ample to give the heat input required by the stove, which may, in the case of large units, range up to 18,000-25,000 cfm of blast furnace gas. To prevent damage to the checkerwork, dome temperature in the top of the stove is usually now controlled to 2000 F maximum.

Draft for the battery of stoves is generally provided by a common stack 8 or 9 ft in diameter and 200-250 ft high. With the trend to greater stove economy, exit gas temperatures have dropped in some cases to as low as 300 F. This means less natural draft from a given stack and in some cases modern stoves need more draft than is available from a stack of practical height. Injectors are sometimes installed for use when back-drafting the furnace. The draft drop through a modern stove is about 0.5 in. water column.

Automatic control of blast temperature contributes much to uniform furnace operation, and has been generally adopted. A connection from the cold blast main may be made into the farthest end of the hot blast main, with an automatically controlled butterfly valve to give the proper mixture. Numerous failures of the lining of hot blast mains, however, have been attributed to the thermal shock caused by this plan. Another plan was therefore introduced in which the mixing air is introduced at each stove into the lower part of the hot blast trunk, so that complete mixing is accomplished before the air reaches the hot blast main.

The operating efficiency of stoves depends greatly on its operation. Incomplete combustion cuts into efficiency heavily, and it is essential that the gas-air ratio be kept correct by its control. Combustion with about 20 per cent excess air assures the elimination of incomplete combustion and yet does not seriously increase stack loss. Radiation is also an important loss, amounting to 295-380 Btu per sq ft of shell surface per hr from uninsulated stoves or 12-15 per cent of the heat input. Insulation may reduce this to as little as 100 or 150 Btu per sq ft per hr, or 4-5 per cent of the heat input. One designer uses a system of insulation having a conductivity of about 0.15 Btu per hr per sq ft per degree of temperature difference in the hotter zones, and 0.27 Btu per hr per sq ft per degree in the cooler zones. Heat lost from an insulated stove runs about 1,300,000 Btu per hr from an insulated stove in quiet air. Air velocity may bring this up by perhaps 25 per cent. The operation of more stoves than are necessary of course increases radiation loss.

Stack losses may be unduly high if stoves are kept on gas longer than necessary. Stack temperature is the best measure of this, and the desirable maximum should be determined and then used as an indication to take the stove off gas.

With proper operation, modern stove efficiency may reach 90 per cent. On the other hand, many existing stoves are operating at 60 per cent (or less) efficiency. Heat balances may range as follows:

	Per cent
Sensible heat in dry stack gas	7 - 15
Sensible heat in moisture in stack gas	0.5 - 1.0
Incomplete combustion	0 - 5.0
Radiation	4 - 15.0
Heat to blast (= efficiency)	60 - 88

Efficient stove operation also requires that the stove on blast be kept on the furnace until the mixer valve closes. Failure to do this means that the stove is being kept at an unnecessarily high heat head for the given blast temperature, which is a rather favorite practice of many stove tenders.

The high temperatures carried in modern stoves require stove refractories of high quality. First class fireclay brick should be used for the greater part of the checkerwork. It has, however, been found advantageous to use super-duty fireclay brick for the combustion chamber and top courses of the checkers.

Modern stoves (about 26 ft × 110 ft) require brick in the following quantities:

Figure 45 — This stove burner, of pressure type, uses a variable speed fan to proportion combustion air in accordance with the gas flow to the stove.

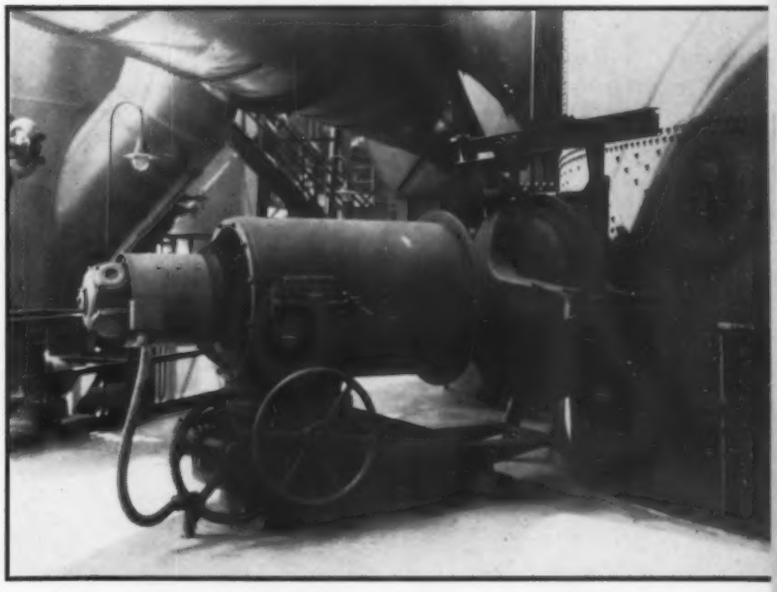


Figure 46 — 45 in. diameter chimney valve on hot blast stove.

Fireclay brick	9 in. equivalent
Checkers	267,000
Dome	18,000
Walls	261,000
Super-duty fireclay brick	
Combustion chamber, etc.	29,000
Top checkers	36,000
Total per stove	611,000

Checkerwork must form a stable construction, yet must be sufficiently flexible to permit the necessary expansion and contraction, and to allow for a reasonable nonuniformity in heat distribution.

Some recent installations employ columns of cast iron or steel, topped by slabs or grids, to support the checkerwork. Others use refractories for the entire supporting structure.

Besides reducing heat loss, insulation of hot blast stoves offers the advantage of keeping the stove shell at a uniform relatively low temperature. This reduces the possibility of shell rupture.

Instruments and meters desirable in the economical operation of stoves include dome temperature recorders and controllers, stack temperature recorders, gas flowmeter, and regulators for gas pressure and gas-air ratio.

Stoves are usually placed in a line parallel to the stockhouse and approximately on the center line of the furnace and cast house. The stove operating platform is generally about level with the cast house or about 20-23 ft above yard level, which is high enough to keep hot metal tracks at general track elevation.

BLOWING EQUIPMENT

The reciprocating blowing engine, driven by steam or by internal combustion of blast furnace gas, has given way in modern installations to the steam turbine-driven centrifugal blower. It is prevailing American practice to install individual blowing for each furnace rather than to blow several furnaces from a common main as is frequently done in Europe. Of course, spare blower capacity is essential to prevent furnace delays arising from blower outage. The blower may be 3, 4 or 5 stages, depending on the characteristics desired. Volumetric characteristics should be such as to supply the maximum wind the furnace can take, as previously discussed. This may vary from 50,000 cfm for an 18 ft furnace to 100,000 or 125,000 cfm for the 27-28 ft furnace, all at a maximum gage pressure of 30-35 psi. Consideration must also be given to the elevation of the plant above sea level, as barometric pressure has a direct effect upon the volume.

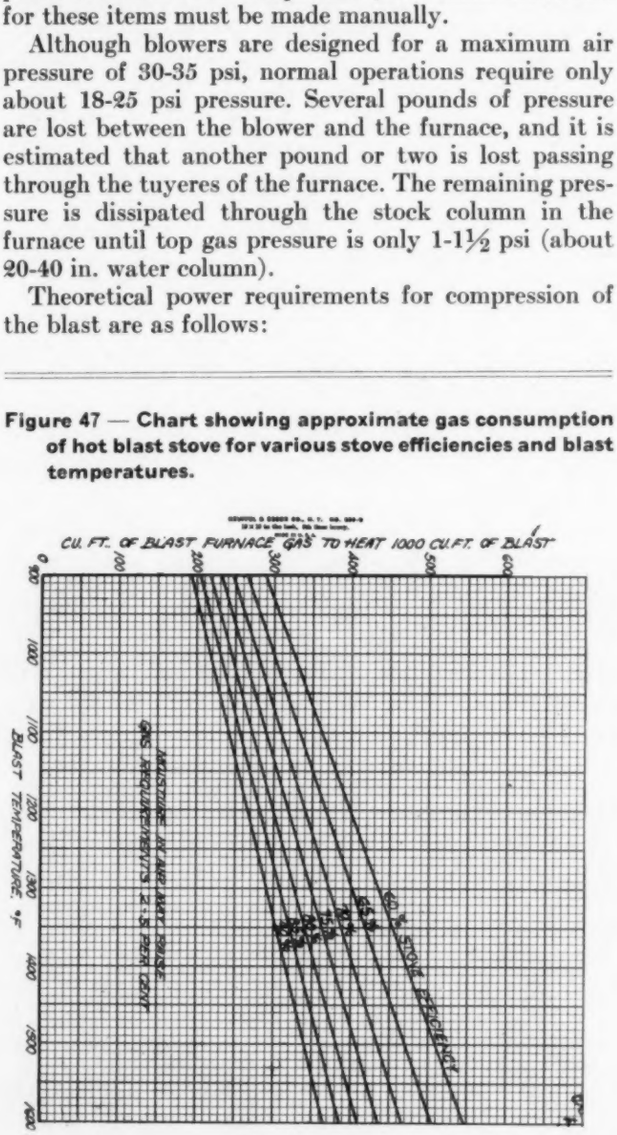
The blower is usually driven by a condensing steam turbine of 8-12 stages.

A constant volume regulator, actuated from a venturi tube or flow nozzle in the intake stack, maintains blast volume at the selected value within 500 cfm plus or minus, regardless of blast pressure, steam pressure, steam temperature or back pressure on the turbine. Some correction may also be made for varying air temperature and barometric pressure, but exact correction for these items must be made manually.

Although blowers are designed for a maximum air pressure of 30-35 psi, normal operations require only about 18-25 psi pressure. Several pounds of pressure are lost between the blower and the furnace, and it is estimated that another pound or two is lost passing through the tuyeres of the furnace. The remaining pressure is dissipated through the stock column in the furnace until top gas pressure is only 1-1½ psi (about 20-40 in. water column).

Theoretical power requirements for compression of the blast are as follows:

Figure 47 — Chart showing approximate gas consumption of hot blast stove for various stove efficiencies and blast temperatures.


CU. FT. OF BLAST FURNACE GAS TO HEAT 1000 CU.FT. OF BLAST
BLAST TEMPERATURE, °F
MOISTURE IN AIR MAY CAUSE
GAS REQUIREMENTS 2-3 PER CENT.
80% STOVE EFFICIENCY

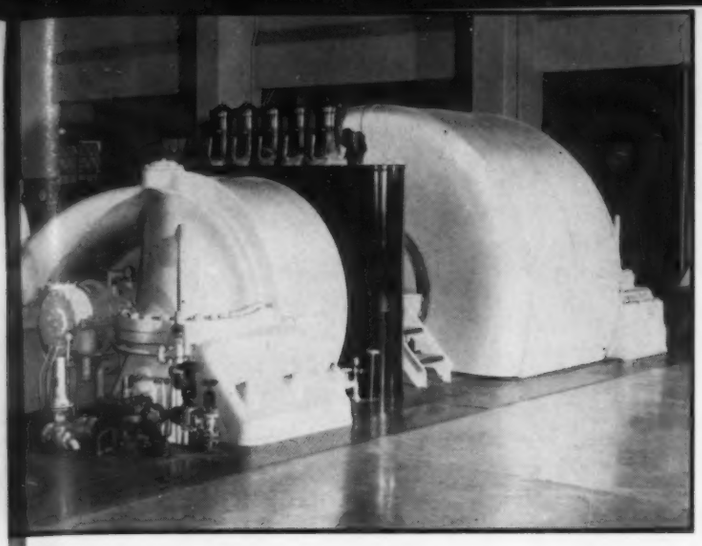


Figure 48 — Blast furnace turbo-blower, rated at 100,000 cfm at 30 psi pressure, and driven by 11,500 hp steam turbine.

Air discharge pressure, psi gauge	Theoretical hp per 1000 cfm of air
6	23
8	30
10	36
12	42
14	47
16	52
18	58
20	62
22	67
24	72
26	76
28	80
30	84

Efficiencies of the air and of centrifugal blowers may range 68-75 per cent, and for reciprocating blowers, 80-90 per cent. Steam consumption, however, may range 9-11 lb per brake hp for turbines and 10-12 lb per brake hp for reciprocating engines. Thus, the gain in the driving end of the turbo blower is largely offset by the lower efficiency of its air and, making total steam consumption comparable, ranging 1200-1700 lb of steam per net ton of coke used in the furnace, depending on equipment and blast pressure. Condenser auxiliaries may add 200 lb of steam per ton of coke. Turbo blowers have a decided advantage from the point of space requirements, first cost and maintenance expense.

Gas engines use 100-140 cu ft of blast furnace gas per brake hp-hr, amounting to 10-15 per cent of the gas production of the furnace. This is only about 75 per cent of the gas needed to make steam to produce one brake hp-hr. Gas engines, however, have extremely high maintenance costs and high first cost, and their use in the United States have been limited.

Figure 49 shows performance curves for a turbo blower rated at 90,000 cfm at 30 psi.

The importance of blowing equipment is emphasized by consideration of the fact that 7500-8000 lb of air must be supplied to the furnace per ton of iron produced.

BLAST CONDITIONING

The idea of reducing the moisture content of the air supplied to the blast furnace is not new, having been experimented with and reported upon by James Gayley in 1904. The drive for greater production during recent years again brought the subject into prominence and resulted in the installation of about 22 blast conditioning units.

As recently applied, blast conditioning has employed the principles of condensation or dehydration, or a combination of the two. Condensation may be effected directly by spraying chilled water or salt brine in contact with the air, or indirectly by means of air-cooling coils. In either case the liquid is cooled by a refrigerating system.

Because of the freezing, the lowest practical dewpoint when using water is 41 F (or about 3 grains of moisture per cu ft of air). If brine is used, subfreezing temperatures can be reached, with lower resultant moisture contents.

The moisture content of air varies with temperature as follows:

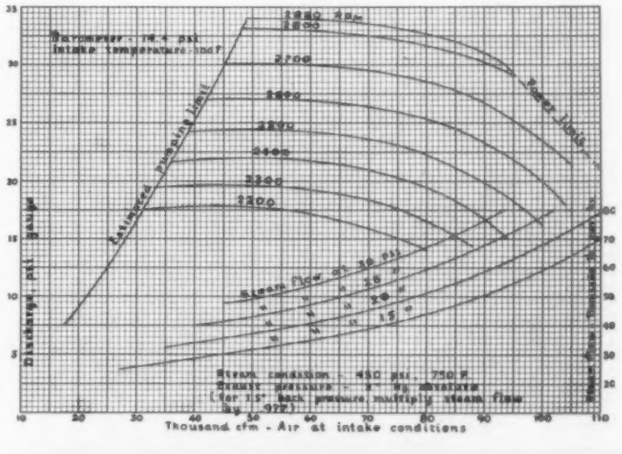
Temperature, F	Grains H_2O per cu ft of air
10	0.77
15	0.98
20	1.26
25	1.54
30	1.96
35	2.37
40	2.87
45	3.43
50	4.06
55	4.83
60	5.74
65	6.79
70	7.98

With direct cooling, the moisture condensed out of the air dilutes brine solution which must be constantly regenerated.

Refrigeration has been applied to the blast either before compression or after. Both plans have their proponents, and both have advantages and disadvantages. In general, precompression refrigeration methods are not recommended for less than 3 grains per cu ft moisture content, while postcompression refrigeration is said to be able to reach 1 grain per cu ft.

Dehydration methods use hygroscopic materials in

Figure 49 — Typical performance curves for turbo blower rated at 90,000 cfm at 30 psi pressure.



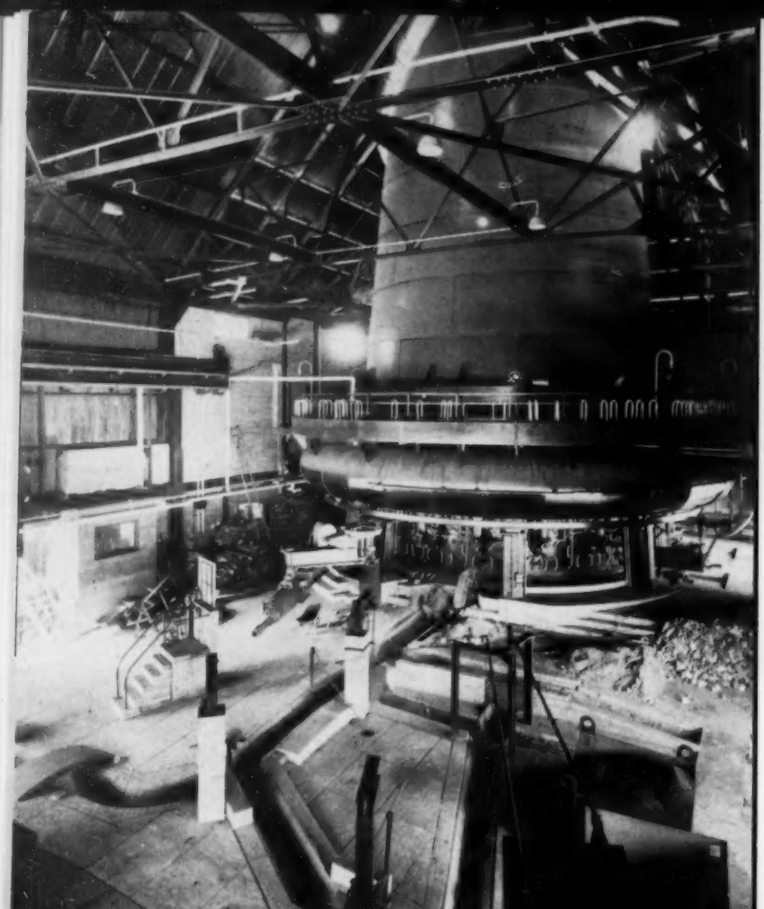


Figure 50 — Furnace cast house, showing arrangement of skimming trough and iron runners.

solution or solid form. Solutions of chloride and bromide of lithium or calcium are flooded over contact plates between which air passes. Heat generated in the absorption must be removed by coolers, and if low dew-points are desired the cooling water must be refrigerated.

Solid dehydrants include silica gel and activated alumina. The granular solids are arranged in beds 1-3 in. thick between fine wire mesh. Several beds are used in series, usually with interposed cooling. The beds must be cut out of the air circuit periodically and reactivated with heated air or a mixture of air and combustion products or steam. Chemical absorption can reduce moisture content of the air to 1 grain per cu ft, and is sometimes used in combination with a refrigeration unit.

There is lack of agreement among proponents of dry blast as to the degree to which moisture removal should be carried, some maintaining that a constant figure of 3 grains per cu ft will give all the advantages, while others hold out for 1 grain per cu ft.

There is little question but that a uniform moisture content in the blast should be conducive to smooth furnace working. However, in spite of the theoretical advantage of low moisture content, and in spite of several operating reports which have indicated gains in iron production of 10-16 per cent with lower coke rates, furnace operators have not been sold on the dry blast. In fact, some experiments have been made in which the moisture content of the blast was held constant by adding steam to the blast, maintaining a content of 4-11 grains per cu ft. These experiments have indicated a somewhat improved control of silicon in the iron, and a somewhat higher iron production and yield with a constant moisture content. For this reason, the addition of moisture to the blast has been adopted as standard practice at quite a number of furnaces.

CASTING

The sand runners and "hand" skimming of years ago have given way to a skimming trough and runners built in heavy, permanent iron castings. The skimming trough is generally lined with fireclay and the runners with a mixture of sand and coke breeze. The casting trough, which should be long enough (18-20 ft) to insure separation of iron and slag contains a dam and skimmer arrangement. Iron runners usually lead to iron spouts, and, to minimize scrap, should be as short as possible.

Some troughs and even runners have been lined with carbon brick, to which metal and slag do not stick, and results have been very satisfactory.

The cinder runner, which leads to a cinder spout or to a granulating pit, should have a drop of at least one inch per foot.

In the earlier days of iron manufacture, all hot metal was cast into pigs in sand beds at the blast furnace. With the development of the pig casting machine, the hot metal was moved to the machine in open top ladles having a sloping shell and flat or dished bottom and mounted in trunnions which rested on the end frames of the car. The metal was poured from the ladle as it was tilted by a hoist at the pig machine while the ladle rested in the trunnion bearings of the car.

Figure 51 — Two strands of endless link chain carry pig molds in this double-strand pig machine.

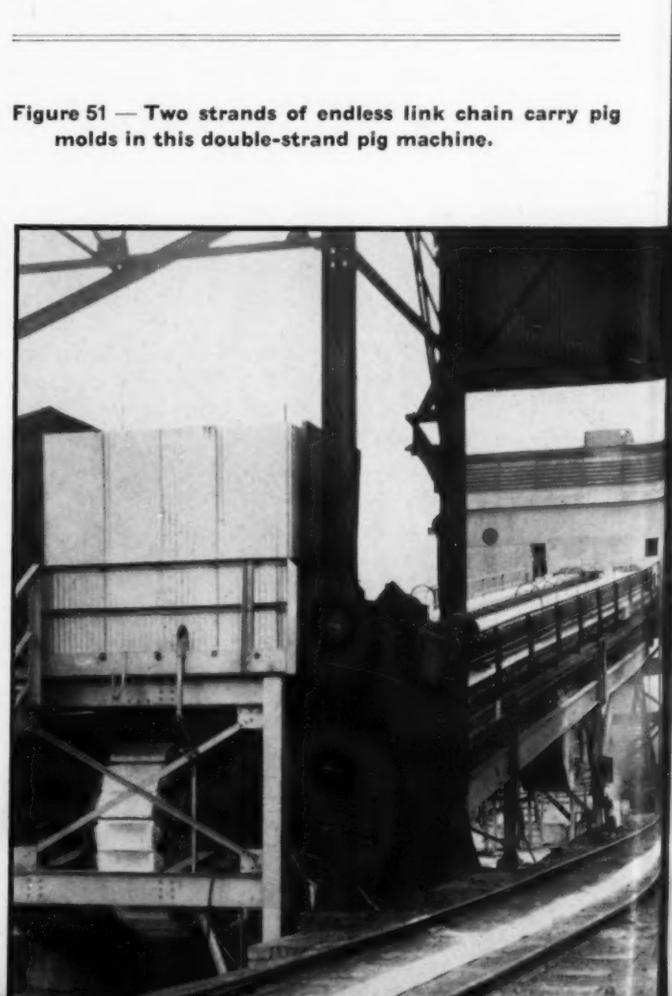


Figure 52 — Typical mixer type iron ladle car with 6-wheel trucks and with brakes and safety attachments as required by the American Association of Railroads for operation over tracks under Interstate Commerce Commission control.

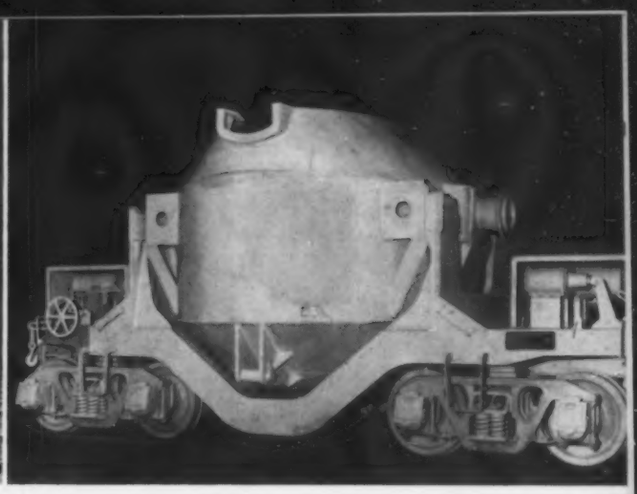


Figure 53 — This 75 ton ladle car is designed with separate ladle to be handled by overhead crane for pouring directly into mixer, open hearth furnaces, or pig machine.

The pig machine consists of one or two strands of pig moulds carried by endless chains and rollers between two large sprocket wheels. The machine, which may range from 125-200 ft long, is driven by a variable speed motor so as to give a chain speed of perhaps 10-50 fpm. The capacity of a double strand machine may run as much as 5 tons per minute, although capacity depends primarily on the length of the machine. Considering the usual delays in switching, changing ladles, etc., a 145 ft machine will take care of about 1700 net tons of iron per day, while one of 200 ft length can handle about 2700 net tons per day.

Somewhat later, additional trunnions were added to the ladle so that it could be lifted from the car by means of a crane and the metal poured into a stationary mixer at bessemer or open hearth plants.

With the exception of increase in ladle capacity, the hot metal car underwent very little change until the introduction of the mixer type car, which is so designed that the ladle remains in the trunnion bearings during all operations. The hot metal is poured by tilting the ladle through the action of an electric motor connected through gearing to the ladle trunnion.

Trucks of the conventional four-wheel type, one at each end of the car, are used on the smaller capacity cars. As the capacity increases or where it is desirable to decrease the concentrated load on bridge members or other trackage, six-wheel trucks are used. Where still greater loads are to be carried, two trucks of either four or six wheels are used at each end of the car.

The design of the mixer type ladle itself consists of a horizontal cylindrical middle section with conical ends to which the trunnions are attached. They are built in capacities ranging from 75 to 210 net tons. Heavy linings of fireclay brick or natural silica "firestone" permit the metal to be held in the cars for 36 hours without forming more skull than will be readily melted by the following cast. This conservation of heat has enabled open hearth and bessemer plants to operate in many cases without stationary mixers, and results in hotter metal and reduced scrap loss. Skull losses may range 1-5 per cent, depending on metal temperature, time held in the ladle, and degree of heat conservation.

Slag disposal varies in the different plants. In some cases, slag is run into cast steel cinder ladles and hauled away from the furnace for dumping. About 400 cu ft is the maximum capacity for such ladles, because of their warping tendency. The slag car should be self-dumping, actuated by air or steam cylinders.

In isolated plants, slag is often carried by the slag runner directly into one or two granulating pits, from which it may be recovered by shovel or overhead bucket crane. Granulation may be affected by a deep pit of water or in many cases by a water jet, under a pressure of about 50 psi, under the end of the cinder spout.

Still another method is the "dry" granulation method, employing a rotating machine containing paddles and using a limited amount of water. This process offers control of the moisture content and of cell structure in the product, which is a semi-granular cellular material having many uses in the construction field.

With any of these methods, the recovered slag is crushed and screened into sizes from 4 in. down to dust. The principal uses of this by-product are in roads, railroad ballast, roofing, filter beds, concrete aggregate, cement, and fertilizer carriers. In an expanded condition, it is useful as a thermal insulation.

BURDENING CALCULATION

Burdening the furnace, calls basically for a survey of the iron ores available, considering their physical condition, quantities and cost, and considering, of course, the iron composition that is desired. The average composition of the ore mix must be such as to permit obtaining this iron analysis. Usually, the charge may be taken from previous or similar practice and modified as needed.

The size of the ore charge depends on the size of the coke charge that may be used, using a coke rate based upon experience. A ratio of ore-to-coke (or burden ratio) of 2.02-2.35, is found in practice and 2.2 is a good average for northern practice. In southern practice, this figure approaches 2.9. The size of the coke charge depends on the size of the furnace and the nature of the coke. Large furnaces require large charges, and figures of 20,000 lb of coke are common in modern practice. On

TABLE XXI — TYPICAL METHOD OF THEORETICAL BURDEN CALCULATION FOR BLAST FURNACE

	Burden	Weight, lb	SiO_2		Al_2O_3		CaO		MgO		Mn		Fe		P		S	
			Per cent	Weight	Per cent	Weight	Per cent	Weight	Per cent	Weight	Per cent	Weight	Per cent	Weight	Per cent	Weight	Per cent	Weight
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	Ore, No. 1	4000	3.40	136.0	2.27	90.8	0.21	8.4	0.23	9.2	0.50	20.0	52.96	2118	0.07	2.80	.....	.....
B	Ore, No. 2	12000	5.26	631.2	2.35	282.0	0.19	22.8	0.19	22.8	0.86	103.2	52.37	6285	0.064	7.68	.....	.....
C	Ore, No. 3	4000	7.27	290.8	2.43	97.2	0.25	10.0	0.24	9.6	0.80	32.0	47.19	1887	0.06	2.40	.....	.....
D	Ore, No. 4	5000	11.28	564.0	2.61	130.5	0.24	12.0	0.33	16.5	0.69	34.5	46.63	2332	0.06	3.00	.....	.....
E	Coke	11400	6.05	683.7	3.00	342.0	0.40	45.6	0.18	20.5	.....	.....	.....	.....	0.014	1.60	1.17	133.4
F	.....	.....	.....	2311.7	.....	942.5	.....	98.8	.....	78.6	.....	189.7	.....	12622	.....	17.48	.....	133.4
G	.....	.....	.....	—281.9	.....	.....	.....	.....	.....	.....	.....	—63.2	.....	.....	.....	.....	.....	.....
H	.....	.....	.....	2029.8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
I	Stone	5702	3.0	171.0	1.20	68.4	51.93	2960.0	1.15	65.8	.....	.....	.....	.....	0.03	1.71	.....	.....
J	.....	.....	.....	2200.8	.....	1010.9	.....	3058.8	.....	144.4	.....	126.5	.....	12622	.....	19.19	.....	133.4

Basic pig iron wanted, 1 per cent Si.

Ratio of ore to coke (from average practice), 2.2.

Ores chosen to give average SiO_2 content of about 6.5 per cent which gives about 50 per cent slag volume.

Basic iron contains about 94 per cent Fe.

From line F, column 14 in above table, 12622 lb Fe 0.94 = 13427 lb pig iron produced.

$$1 \text{ per cent required } 1 \times \frac{60}{28} = 2.1 \text{ per cent } SiO_2.$$

13427 lb pig iron $\times$ 0.021 = 281.9 lb SiO_2 for Si in pig iron. (Line G, column 4).

From F-4 in above table, 2311.7 — 281.9 = 2029.8 lb of SiO_2 to be fluxed (H-4).

Use ratio of: (CaO + MgO) ÷ (S_iO_2 + Al_2O_3 = 1. This ratio may vary from 0.97 to 1.03, according to the ratio of acids to bases needed in the slag for the type of iron wanted.)

From H-4 and F-6, 2029.8 + 942.5 = 2972.3 = lb of lime required for SiO_2 and Al_2O_3.

Ore and coke contain 98.8 lb CaO + 78.6 lb MgO = 177.4 lb of lime (F-8 and F-10).

2972.3 — 177.4 = 2794.9 lb lime required.

Stone shows CaO + MgO = 53.08 per cent (I-7 and I-9), and SiO_2 + Al_2O_3 = 4.2 (I-3 and I-5).

SiO_2 and Al_2O_3 in stone needs 4.2 per cent lime to flux.

53.08 — 4.2 = 48.88 per cent available lime in stone.

2794.9 lb lime required ÷ 0.4888 = 5702 lb stone (I-2).

Amounts of various components in stone are then figured and line I completed.

Experience shows about 1/3 of Mn to enter slag (some use ½).

1/3 × 189.7 = 63.2 lb Mn to slag (G-12), leaving 126.5 lb Mn to iron (J-12).

All SiO_2 except that needed for Si in iron enters the slag. All Al_2O_3, CaO and MgO enter slag. All P enters the iron.

Iron and slag analyses are then as follows:

	Component	Per cent
Iron:	Fe	94.00
	P = 19.19 ÷ 13427 =	0.14 (from J-16)
	Mn = 126.5 ÷ 13427 =	0.94 (from J-12)
	Accepted Si	1.00
	Accepted S	0.05
	C, by difference	3.87

		Wt lb	Per cent
Slag:	SiO_2 (J- 4)	2200.8	33.10
	Al_2O_3 (J- 6)	1010.9	15.40
	CaO (J- 8)	3058.8	46.09
	MgO (J-10)	144.4	2.17
	MnO = 63.2 lb Mn × 1.29 (G-12)	81.5	1.23
	S (J-18)	133.4	2.01
	Total Slag	6629.8	100.00

13427 ÷ 2000 = 6.71 net tons pig iron per charge.

6629.8 lb slag ÷ 13427 = 49.3 per cent slag volume.

6629.8 ÷ 6.71 = 987 lb of slag per ton of pig iron.

From J-8, J-10 and J-4:—

(3058.8 + 144.4) ÷ (2200.8 + 1010.9) = 0.998, ratio of bases to acids in slag.

(3058.8 + 144.4) ÷ 6629.8 = 48.2, percentage of bases in slag.

11400 ÷ 6.71 = 1695 lb of coke per ton of pig iron.

From column 2:—

25000 lb ore ÷ 11400 = 2.2, ratio of ore mix to coke (or burden ratio).

5702 ÷ 25000 = 22.8 per cent, stone to ore mix.

5702 ÷ 6.71 = 850 lb of stone per ton of iron.

Miscellaneous:

Lb Fe_2O_3 needed for 100 lb of pig iron = 0.94 × 160 ÷ 112 = 134.3.

Lb of ore needed for 100 lb of pig iron = 0.94 × 100 ÷ per cent of Fe in dry ore.

Stone required by coke = (2 × per cent ash in coke) + (3.5 × per cent sulphur in coke).

Slag made by coke = per cent ash in coke + per cent sulphur in coke + fluxing components of its stone requirements.

(SiO_2 + Al_2O_3 in ore and coke minus CaO and MgO in ore and coke) × 2 gives approximate amount of stone required.

Under ordinary conditions, 50-75 per cent of total Mn in the charge is reduced to metal. The charge should contain 2/3 - 1 per cent Mn to give about 1 per cent Mn in the iron.

90-100 per cent of the phosphorus present in the charge enters the iron.

Ordinary slags will not hold much over 2 per cent of sulphur. If there is a deficiency of slag-forming material in the ore, silica must be added to the charge.

Usual practice averages 2.7-2.95 lb of raw material smelted per lb of carbon in the coke.

The foregoing method of burden calculation assumes that Al_2O_3 is acid. Some prefer to consider it a neutral component, in which case lime requirements are taken as 1.5 × the silica in the burden.

smaller furnaces, coke charges are found ranging down to 6,000 lb or even less.

The excess acids in the charge must be fluxed with lime. After determining the available base in the limestone to be used, the stone requirements may be calculated. Iron and slag analysis may then be estimated. Table XXI shows a typical calculation of a theoretical burden, which may then be modified in practice as experience may dictate.

There has been some difference in opinion as to the nature of Al_2O_3 in the blast furnace process. The majority of operators consider it an acid, as is done in Table XXI. Others consider it neutral, and multiply the silica to be fluxed by 1.5 to determine the lime required.

BLOWING-IN

A new lining requires a certain amount of drying before the furnace is filled. Some years ago drying was accom-

plished by coke fires maintained in dutch ovens built outside of the iron notch or tuyere openings at the side of the hearth. The furnace top was kept closed and combustion gases were brought down through the dust-catcher. If gaseous fuel is available, burners may be placed near the bottom of the furnace. These methods of drying required about two weeks, and with the drive for iron production through the war years, it became quite general to reduce this period. If blast furnace gas is available from other furnaces, the use of hot blast from stoves is used, and with this method drying time has in some cases been reduced to 72 hr or even less.

Furnace filling usually starts with 80,000-90,000 lb of coke on the hearth, with no fluxing agent. This should come up to the lower edge of the tuyeres. Next, 3-4 ft of eordwood is placed on the coke, with small kindling and oily waste 2-3 ft in front of and above each tuyere. Tuyeres are then placed in the tuyere coolers and closed up to guard against fire.

Filling then progresses, using the regular coke charge and some limestone in gradually increasing amounts. Some blast furnace slag is also charged. After about 12 rounds, ore is introduced into the charge and gradually increased in successive rounds. When the furnace is full to about 30 ft from the stockline, the top is inspected and perhaps adjusted. The iron notch is then plugged, the blowpipe put up, and the filling completed. Tables XXII, XXIII and XXIV give data from a blow-in typical of modern practice.

If the furnace gas main is connected to others, the blower is started and the gas main opened, allowing gas from the other furnaces to fill the mains back to a closed valve between dust catcher and gas washer. Steam is introduced into the dust catcher and exhausted through the furnace bleeder. The furnace is then lit, wind put on, and the dust valve at the bottom of the dust catcher cracked. When furnace gas has pushed the steam out, the valve between dust catcher and washer may be opened, and the dust valve and furnace bleeder closed.

If the furnace is isolated, the hot blast valve and

TABLE XXII — FURNACE BLOW-IN

Series	Charges	Coke per charge lb	Limestone, lb			Furnace slag charged	Ore per charge, lb					Open hearth slag	Ratio, ore to coke	Tons pig per charge	Slag volume per net ton iron	Mn in metal	Filling
			Actual	Theo	Diff		Mc-Cook	Cliff	Tilden	Saga	Total						
1	3	20,000	2,400	3,000	—600	4,000											
2	3	20,000	2,400	3,000	—600	3,800											
3	3	20,000	2,400	3,000	—600	3,600											
4	3	20,000	2,400	3,000	—600	3,600											
5	5	20,000	5,800	6,067		2,000	3,700	3,700	2,000	600	10,000		0.50	2.48	3,310	0.98	(oosccc)
6	5	20,000	6,000			2,000	4,200	4,200	2,000	600	11,000		0.55				
7	5	20,000	6,200			2,000	4,600	4,600	2,000	800	12,000		0.60				
8	5	20,000	6,400			1,000	5,100	5,100	2,000	800	13,000		0.65				
9	5	20,000	5,400			1,000	6,100	6,100	1,000	800	14,000		0.70				
10	5	20,000	5,600	5,893		1,000	7,000	7,000	1,000	1,000	16,000		0.80	4.25	1,760	1.00	
11	5	20,000	6,200			1,000	8,000	8,000	1,000	1,000	18,000		0.90				
12	5	20,000	6,600			1,000	9,000	9,000	1,000	1,000	20,000		1.00				(Furnace
13	5	20,000	7,000			1,000	10,000	10,000	1,000	1,000	22,000		1.10				full)
14	5	20,000	7,400			1,000	10,900	10,900	1,000	1,200	24,000		1.20				
15	5	20,000	7,800	8,011		1,000	11,900	11,900	1,000	1,200	26,000		1.30	6.98	1,370	0.82	
16	5	20,000	8,400			1,000	12,900	12,900	1,000	1,200	28,000		1.40				
17	5	20,000	8,800			1,000	13,800	13,800	1,000	1,400	30,000		1.50				
18	5	20,000	9,200				15,100	15,100	1,000	800	32,000	1,500	1.60				
19	5	20,000	9,600				16,100	16,100	1,000	800	34,000	1,500	1.70				
20	5	20,000	10,000	10,076			22,800	11,400	1,000	800	36,000	1,500	1.80	9.78	1,170	0.95	(oosccc)
21	5	20,000	10,300				23,600	11,800	1,000	1,100	37,500	1,400	1.88				
22	5	20,000	10,600				24,600	12,300	1,000	1,100	39,000	1,400	1.95				
23	5	20,000	10,900				25,600	12,800	1,000	1,100	40,500	1,400	2.02				
24	5	20,000	10,900				25,600	12,800	1,000	1,100	40,500	1,400	2.02				
25	5	20,000	10,900	10,941			25,600	12,800	1,000	1,100	40,500	1,400	2.02	11.00	1,110	0.94	
26	5	20,000	10,900				25,600	12,800	1,000	1,100	40,500	1,400	2.02				
27	5	20,000	10,900				25,600	12,800	1,000	1,100	40,500	1,400	2.02				
28	5	20,000	10,900				25,600	12,800	1,000	1,100	40,500	1,400	2.02				

18 skips of coke of 5,000 lb each in hearth. No lime for flux. 4 ft of cord wood on coke, then filling above.
Wind, 20,000 cfm at start, 1,000 cfm added each hour up to 50,000 cfm.

TABLE XXIII — ANALYSIS OF BURDEN MATERIALS

Material	Fe	Phos	Mn	SiO_2	Al_2O_3	CaO+MgO
McCook	53.65	0.048	0.25	8.15	0.69	0.18
Cliff	52.10	0.100	0.26	7.30	2.41	0.54
Tilden	38.90	0.036	0.10	41.30	0.62	0.42
Sagamore	37.16	0.250	8.00	7.29	2.98	0.80
Lake Erie stone	0.66	0.042	....	3.06	0.39	51.24
Furnace coke	1.19	0.027	....	5.55	3.31	0.88
Open hearth slag	15.00	0.050	7.00	15.00	3.60	37.82

cold blast valve are opened. The top of the furnace is also opened. When blast appears at the furnace, the lighting process may be begun. Because of the danger of explosions with this procedure, steam is often used to drive air out of the dust catcher and gas mains before gas is brought down through them.

In either of the preceding cases, the furnace is generally lit by running red hot rods through each tuyere peep hole into the oily waste placed in front of the tuyere, although in some cases hot blast from other adjacent furnaces is used.

Blast is usually started with a volume of about 25 per cent of full wind and stepped up at a rate of 1000 cfm per hr until 45,000-50,000 cfm is reached. It is then increased slowly up to the best operating volume. Some operators prefer to build up the blast volume more slowly, using steps of 500 cfm per hr.

The bleeder can be closed about 15 min after the blast is started, and the gas put into the mains for use. In approximately 15 hr, or after a good ladle of slag is taken from the cinder notch, the iron notch may be opened with the drill at a low angle. The first cast should be hot.

Some operators, instead of continually changing the burden when filling and blowing in, prefer to charge 4 or 5 rounds of the regular burden charge, each with about 3 blank coke charges (ore-to-coke ratio of about 0.55), then 4 rounds of regular burden, each with 2 coke blanks (ore-to-coke ratio of about 0.75), then about 15 regular rounds plus one extra coke charge (ore-to-coke ratio about 0.9), followed by 10-15 regular rounds with one extra coke charge following each 2 regular rounds (ore-to-coke about 1.5). The extra coke is gradually withdrawn until the ore-to-coke ratio approximates 2. Many operators feel that the coke blanks used in this method scour the brickwork excessively.

Instead of closing the iron notch before lighting the furnace, some operators prefer to allow the gas to blow out and burn through a 4 in. pipe placed in the notch, as previously mentioned.

BLOWING-OUT

In blowing out a furnace, it was formerly general practice to stop charging and allow the stock line to drop in the furnace while gradually reducing the blast, until most of the molten iron and slag are tapped out. Top temperatures increase materially as the stock drops in the furnace. In some cases a heavy layer of limestone was put into the furnace on top of the last charge so as to put a lot of unexplosive CO_2 in the top of the furnace. In other instances, heavy layers of ore were charged to hold top temperature. Water sprays through the furnace top also were used. After the stock dropped 30-35 ft below normal, the wind was removed and the stock

TABLE XXIV — ANALYSIS OF IRON AND SLAG FROM BLOW-IN

ANALYSIS OF FIRST 19 CASTS

Cast No.	Si	S	P	Mn
1	3.60	0.024	0.212	0.94
2	4.40	0.018	.....	.....
3	3.44	0.022	0.200	1.26
4	2.59	0.029	.....	.....
5	2.70	0.030	0.214	1.22
6	2.25	0.022	.....	.....
7	2.50	0.024	0.200	1.26
8	2.46	0.028	.....	.....
9	2.47	0.028	0.200	1.24
10	2.69	0.020	.....	.....
11	3.02	0.017	0.188	1.30
12	2.69	0.018	.....	.....
13	1.70	0.027	0.192	1.20
14	1.98	0.020	.....	.....
15	1.95	0.020	0.200	1.22
16	1.35	0.018	.....	.....
17	1.77	0.034	0.178	1.02
18	1.85	0.028	.....	.....
19	1.44	0.024	0.184	1.00

AVERAGE ANALYSIS OF SLAG FROM FIRST 11 DAYS

(FURNACE LIT 11:55 AM OCTOBER 12)

Date	SiO_2	Al_2O_3	CaO	MgO	MnO	S	FeO
10-13	39.40	11.50	37.60	2.96	1.99	1.10	6.00
10-14	39.14	11.73	44.00	1.61	1.61	1.62	1.10
10-15	33.70	14.28	49.00	1.31	0.25	2.32	0.30
10-16	36.20	13.12	48.00	1.13	0.37	1.86	0.25
10-17	36.50	12.05	48.00	1.91	0.40	1.88	0.20
10-18	37.52	11.65	47.80	1.52	0.49	1.64	0.20
10-19	37.40	11.15	45.00	4.06	1.06	1.46	0.60
10-20	39.04	11.88	40.40	6.38	1.10	1.50	0.45
10-21	38.00	11.71	40.60	7.56	1.04	1.58	0.30
10-22	38.80	11.61	41.60	6.03	0.94	1.54	0.25
10-23	38.06	11.36	41.00	7.41	1.03	1.58	0.35

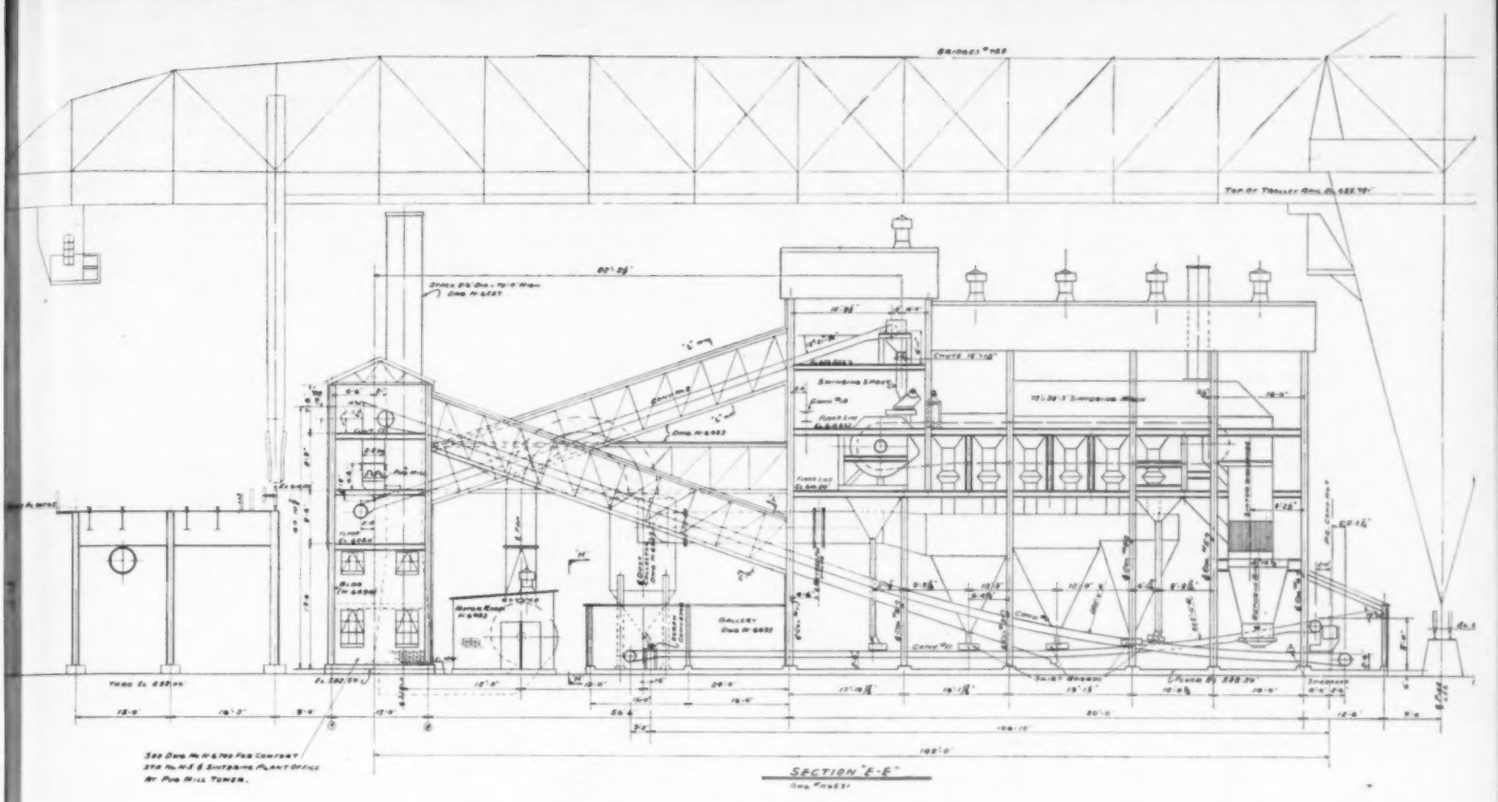


Figure 54 — Cross section through a sintering plant of continuous pallet type.

remaining in the furnace was wet down and rabbled out. Hydraulic flushing replaced rabbling at many plants, and with liberal water supply under adequate pressure and a liberal hole in the bosh, furnaces have been emptied in as little as 3 hr. Details of the blow-out varied widely with the different operators — and for that matter, still do.

In recent years, blowing out with nut coke and a full furnace has found increasing favor. In this method, the burden is taken off the furnace but the stockline is maintained at regular level by charging straight nut coke. Wind is gradually reduced, while top temperature is held down by water. The furnace is cast on regular schedule right up to the last cast. After the blast is cut off, and the coke cooled sufficiently, coke is washed out of tuyere cooler holes through chutes into railroad cars. A schedule of a blow-out by this method follows:

Hours

0. . . . Open hearth slag, roll scale, scrap, etc. taken off burden and replaced by 2000 lb ore.
4. . . . 10,000 lb silicious ore charged as extra.
6. . . . 10,000 lb silicious ore charged as extra.
8. . . . 300 lb stone taken off burden.
10. . . . Stone completely removed from burden.
15. . . . Water sprays put in 3 gauge-rod holes; one of these also connected to steam line.
Remainder of regular burden taken off.
Start charging straight nut coke with 150 gal of water per skip.
Keep furnace full.
17. . . . Wind cut 10,000 cfm; 2000 cfm more cut off each hour for next 5 hr.
Keep top temperature under 600 F, starting water sprays when needed.
32. . . . Calculated last cast made. Be sure furnace is moving regularly.
34. . . . Another cast made for insurance. Steam turned into dust catcher. Furnace drafted, blowpipes taken down and tuyeres plugged. Fourth water spray put in gauge-rod hole. Bells blocked open. Salamander drained.
38. . . . Water appeared at bosh.
48. . . . Two coolers pulled and chutes installed to carry away coke as it is removed. Coke washed out by water lines through cooler holes at a rate of about one car per hr per cooler.

Some operators follow a procedure similar to the foregoing except that the coke in the furnace is cooled down by introducing steam through the tuyeres.

This method of blowing out is fast and economical, and has been widely adopted.

Another detail of blowing out which has speeded up the process greatly is the practice of tapping out the salamander through a hole drilled through the furnace foundation and into the bottom, so that the salamander may be drained out in molten state.

SINTERING PLANT

The sintering plant should be located at the most advantageous place and not put in some corner remote from all operating units, as was often done when the unit was a dust hole.

The size of a sintering plant depends on the amount of raw material available, the amount of sinter required, and the characteristics of the materials to be sintered. The plant should not be built to handle flue dust alone, as the limited supply of dust makes the operation irregular and costly. Furthermore, the carbon in normal flue dust provides more fuel than is needed to sinter the dust alone. This excess fuel can be used to sinter fine ore mixed with the flue dust. The sintering mixture should contain 3-5 per cent carbon.

To produce uniform sinter, the materials entering the machine must be uniformly mixed and regularly fed. This requires an adequate complement of storage bins, with automatic feeding equipment, so that definite proportions of raw materials can be maintained in the feed to the machine at all times.

Sintering plants fall into three principal types:

1. Rotary kilns, 9-14 ft in diameter × 125-200 ft long, and with a capacity of 200-300 tons of sinter per day. These units are similar to the conventional rotary kiln but modified so as to have a temperature distribution that concentrates the sintering action in a relatively short zone. Thus, the coating which tends to build up on the kiln wall in the sintering zone is easily removed by a water-cooled cutter bar without interrupting kiln operation.
2. The batch-type machine, in which the raw materials are charged into a tilting pan, about 10 ft × 30 ft mounted on trunnions. Suction up to 50 in. water column is applied and the material is ignited by means of an ignition hood which is moved over the pan. The bed of material in the pan may range 7-17 in. in depth, and sintering progresses down through the bed at a rate of about one inch per minute. When sintering is complete, the pan is dumped.
3. The continuous pallet-type machine, in which a traveling grate passes over suction wind boxes at a speed to burn the carbon out of the material by the time the grates dump at the end of the machine.

It is the last-named type which has found greatest favor in the blast furnace field, and sintering plants recently constructed in connection with blast furnace plants follow a general pattern (Figure 54). Material to be sintered is dumped into 2-4 track hoppers, each of 2000-3700 cu ft capacity, from where it is carried by belt conveyors to shaking screens 4 or 5 ft wide × 10 ft long, with ¼ in. stroke and screen cloth from ⅜ in. × 3 in. to ½ in. × 5 in. After screening, the material is conveyed to storage bins, of which there may be 4-7, each of 3500-6500 cu ft capacity. One bin usually contains coke breeze, one may contain mill scale, and the remainder are used for flue dust or fine ore screenings as needed.

In the modern large unit, belt conveyors are usually 30 in. wide and travel at about 260 fpm, giving a handling capacity of approximately 400 tons per hour up to the storage bins.

From the storage bins, rotating disc feeders discharge material from their respective bins at a predetermined rate on to a conveyor, over which the material is carried to pug mills. After going through the pug mills, the material is delivered to a swinging spout which spreads material uniformly across the grates at the feed end of the sintering machine, to a depth of 10-14 in.

The sintering machine is a continuous pallet conveyor about 72 in. wide and 50-89 ft long, and driven by an adjustable speed motor (2:1 or 3:1 ratio) so geared as to give a time range of about 10-25 minutes for the grate to travel from one end of the machine to the other end. Underneath the sintering machine are 6-16 wind boxes, each about 6 ft square, connected to a common suction main. Suction to the extent of 24-30 in. of water column is provided by a fan of such capacity as to give 200-250 cfm per sq ft of grate area. The fan is designed to handle gases at a temperature of 250-300 F, and is connected to an unlined steel stack 5-6 ft in diameter and about 70 ft high.

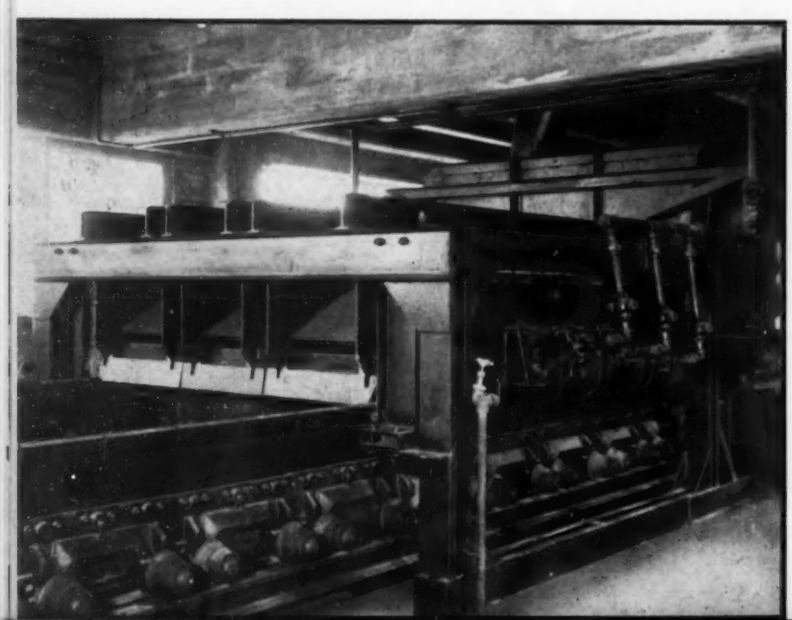
The ignition furnace is an important item in the performance of the sintering machine. In the past, such furnaces were made quite short, often with a spread of only 12 in. along the grate. Modern design runs to furnaces with a length of about 7 ft, so that an ignition time of 40-60 sec is provided, which has been quite satisfactory (see Figure 55).

The furnace is fired with coke oven gas when available; otherwise, fuel oil is generally used. In a 7 ft furnace, three burners may be used in each side, staggered from side to side and inclined at different angles toward the gate so that flame impingement is well distributed over the grate area within the furnace.

Product from the sintering machine is discharged over a 1½ in. grizzly chute. It is desirable to have the sintering plate so located that the sinter may be chuted directly into the ore yard. Fines from the final screening are returned to a "hot return fines bin" for reprocessing through the machine.

The capacity of a sintering machine varies with the nature of the material to be processed, but depends principally on grate area. Figures from existing plants show 0.075-0.14 tons of sinter per hr per sq ft of grate area. (See Table XXV). In normal practice, the product represents 80-85 per cent of the weight of material charged to the machine.

Figure 55 — Ignition furnace, fired with coke oven gas, for modern sintering plant.



UTILITY CONSUMPTION

Power consumptions of a blast furnace plant are approximately as follows:

TABLE XXV — DATA FROM TYPICAL SINTERING MACHINES

No.	Machine size			Cfm	Fan capacity		Fan capacity, cfm per sq ft of grate area	Tons of sinter per machine-hour	Tons of sinter per hr per sq ft of grate area	Vacuum, in. × cfm	Vacuum × cfm ÷ tons of sinter per hr	Fan hp per ton of sinter	Sinter mixture
	Width, in.	Length, ft	Area, sq ft		Vacuum, in. water column	Motor hp							
1	42	25	88	26,000	20	125	295	10	0.113	520,000	52,000	12.5	Flue dust
2	72	76	456	100,000	24	600	220	45	0.098	2,400,000	53,333	13.4	Half ore, half flue dust
3	72	76	456	100,000	20	600	220	40	0.088	2,000,000	50,000	15.0	Flue dust and ore
4	72	51	306	75,000	24	450	245	28	0.092	1,800,000	64,285	16.1	Stockpile dust
5	72	83	498	115,000	27	750	231	50	0.100	3,105,000	62,100	15.0	Magnetic concentrates and flue dust
6	42	66	231	50,000	20	300	216	18	0.078	1,000,000	55,555	16.7	Magnetic concentrates
7	72	64	384	90,000	20	500	233	30	0.078	1,800,000	60,000	16.7	Flue dust and filter cake
8	42	25	88	26,000	20	125	295	7.5	0.085	520,000	69,333	16.7	Flue dust
9	72	64	384	100,000	20	600	260	35	0.091	2,000,000	57,143	17.2	Flue dust, ore and roll scale
10	72	64	384	100,000	22	600	260	32	0.083	2,200,000	68,750	18.8	Flue dust
11	72	64	384	100,000	21	600	260	30	0.078	2,100,000	70,000	20.0	Flue dust, sludge and filter cake
12	42	60	210	60,000	20	300	285	15	0.072	1,200,000	80,000	20.0	Flue dust and ore
13	72	89	534	126,000	..	1000	235	75	0.14	.....	.....	13.3	Flue dust and ore
14	72	51	306	54,000	24	350	176	37	0.12	1,300,000	35,000	9.4	Flue dust
15	72	89	534	100,000	24	600	187	60	0.112	2,400,000	40,000	10.0	Flue dust and ore

Electric power

Total, furnace and stoves	4 — 6 kwhr per net ton of iron.
Sinter plant	11 — 23 kwhr per net ton of dry sinter.
Pig machine, 0.6 — 0.75 kwhr d-c at 75 per cent =	0.8 — 1.0 kwhr per ton of iron pigged.
Unloading and stocking ore	0.6 — 1.0 kwhr per ton of iron produced.
Slag plant	6 — 8 kwhr per ton of slag.
Water pumping (180 — 300 kw average)	6 — 10 kwhr per ton of iron.
Total consumption	15 — 21 kwhr per ton of iron.

Blast furnace plants, including auxiliaries, employ 50-70 motors per furnace, and show 1,800-2,500 connected hp per furnace, the values decreasing as the number of furnaces increases.

Ratio of average kw consumption to connected hp = 0.10-0.14 per cent, excluding water pumping, or 0.20-0.25 per cent including pumps.

Steam

Blowers and auxiliaries	1,400-1,900 lb of steam per net ton of coke.
Sinter plant	30 — 90 lb of steam per ton of dry sinter.
Pig machine	25 — 50 lb of steam per ton of iron pigged.
Blast furnace miscellaneous	Up to 100 lb of steam per ton of iron produced.

The last item included 7-10 lb of steam per ton for mud gun, etc., steam used in gas mains, stove cleaning, etc.

Water

	Gpm
Sinter plant	200
Pig machine	1,000
Gas washer (See "Gas Cleaning")	1,500 — 2,500
Furnace and stoves	2,000 — 4,000
Blower condenser	5,000 — 8,000
Blower cooling	200 — 350
Boiler feed for furnace and blower steam	— 30

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APPENDIX

Company	Furnace identification	Hearth diameter ft-in.	Capacity net tons
Alan Wood Steel Company			
Swedeland, Pennsylvania	2	15-0	198,950
	3	18-0	255,850
Total			454,800
American Rolling Mill Company			
Ashland, Kentucky	1	13-9	148,000
	Norton	14-6	188,000
	Bellefonte	25-9	430,000
			766,000
Hamilton, Ohio	1	17-0	265,000
	2	18-0	292,000
			557,000
Sheffield Steel of Texas			
Houston, Texas	*1	22-0	245,300
Total — American Rolling Mill Company			1,568,300
Bethlehem Steel Company			
Bethlehem, Pennsylvania	A	20-0	300,000
	B	19-0	237,600
	C	26-0	432,000
	D	19-0	237,600
	E	19-0	237,600
	F	19-0	237,600
	G	19-0	237,600
			1,920,000
Johnstown, Pennsylvania	E	22-6	324,000
	F	18-0	198,000
	G	25-0	378,000
	H	17-6	198,000
	J	20-0	270,000
	K	19-0	270,000
	L	18-0	252,000
***Government owned**			1,890,000

Company	Furnace identification	Hearth diameter ft-in.	Capacity net tons
Lackawanna, New York	A	20-6	279,600
	B	20-6	300,000
	C	27-0	432,000
	F	25-0	378,000
	G	26-0	410,400
	H	27-0	432,000
	J	22-0	324,000
			2,556,000
Sparrows Point, Maryland	A	23-0	420,000
	B	23-0	410,400
	C	24-0	410,400
	D	26-0	432,000
	E	19-0	303,600
	F	19-0	303,600
	G	25-9	432,000
			2,712,000
Steelton, Pennsylvania	A	18-0	228,000
	B	22-0	348,000
	E	18-0	228,000
			804,000
Total — Bethlehem Steel Company			9,882,000
The E and G Brooke Iron Company			
Birdsboro, Pennsylvania	3	14-0	154,400
Colorado Fuel and Iron Corporation			
Pueblo, Colorado	A	16-9	198,000
	D	19-4	252,000
	E	20-6	264,000
	F	21-9	282,000
Total			996,000

Company	Furnace identification	Hearth diameter ft-in.	Capacity net tons
Crucible Steel Company of America			
Midland, Pennsylvania	2	18-0	255,350
	3	18-0	282,250
Total			537,600
Eastern Gas and Fuel Associates — Mystic Iron Works			
Everett, Massachusetts	Everett	17-0	176,400
Ford Motor Company			
Dearborn, Michigan	H	18-6	252,000
	B	18-6	252,000
Total			504,000
Globe Iron Company			
Jackson, Ohio	Globe	14-6	84,000
Inland Steel Company			
Indiana Harbor, Indiana	1	20-0	329,000
	2	19-0	302,400
	3	17-3	266,800
	4	20-0	324,050
	5	25-9	450,000
	6	25-0	427,000
	*A	25-9	450,250
	*B	25-9	450,250
Total			2,999,750
Interlake Iron Corporation			
Erie, Pennsylvania	Perry	15-7	171,350
South Chicago, Illinois	A	15-7	216,400
	B	19-6	296,500
			512,900
Toledo, Ohio	A	19-6	237,600
	B	21-0	268,800
			506,400
West Duluth, Minnesota	Zenith	14-0	150,000
Total — Interlake Iron Corporation			1,340,650
International Harvester Company Wisconsin Steel Works			
South Chicago, Illinois	1	18-0	235,850
	2	18-0	235,850
	3	18-6	247,950
			719,650
Jackson Iron & Steel Company			
Jackson, Ohio	Jackson	14-3	90,000
Jones & Laughlin Steel Corporation			
Aliquippa, Pennsylvania	1	28-6	408,000
	2	21-6	264,000
	3	28-6	408,000
	4	27-0	360,000
	5	26-6	360,000
			1,800,000
Cleveland, Ohio	1	18-6	249,600
	2	17-7	230,400
			480,000
Pittsburgh, Pennsylvania	1	20-0	288,000
	2	24-0	384,000
	3	21-6	264,000
	4	18-9	288,000
	5	20-0	288,000
	6	18-6	288,000
			1,800,000
Total — Jones & Laughlin Steel Corporation			4,080,000
* Government owned.			

Company	Furnace identification	Hearth diameter ft-in.	Capacity net tons
Kaiser Company, Inc.			
Fontana, California	1	25-6	431,400
Koppers Company, Inc., Blast Furnace Division			
Granite City, Illinois	A	17-9	193,550
	B	19-6	233,850
			427,400
E. J. Lavino and Company			
Sheridan, Pennsylvania	Sheridan	12-0	36,300
Reusens, Virginia	Oriskany	12-0	36,300
			72,600
Lone Star Steel Company			
Daingerfield, Texas	*1	23-0	399,850
National Steel Corporation Great Lakes Steel Corporation			
Detroit, Michigan	A	17-9	263,000
	B	27-3	443,000
	C	27-3	394,000
			1,100,000
Hanna Furnace Corporation			
Buffalo, New York	1	15-6	175,000
	2	15-6	175,000
	3	14-5	157,000
	4	20-0	273,000
			780,000
Weirton Steel Company			
Weirton, West Virginia	1	25-6	411,250
	2	23-6	369,600
	3	25-6	419,350
			1,200,200
Total — National Steel Corporation			3,080,200
New Jersey Zinc Company			
Palmerton, Pennsylvania	1	12-6	77,300
	2	10-0	57,100
			134,400
Newberry Lumber & Chemical Company			
Newberry, Michigan	1	7-0	32,000
Pittsburgh Coke & Chemical Company			
Neville Island, Pennsylvania	Neville	22-0	320,000
Pittsburgh Ferromanganese Company (R.F.C.)			
Chester, Pennsylvania	Delaware	14-6	127,000
Pittsburgh Steel Company			
Monessen, Pennsylvania	1	19-0	276,850
	2	19-0	276,850
	*3	26-6	432,100
			985,800
Republic Steel Corporation			
Birmingham, Alabama	1	17-0	191,000
	2	17-0	185,000
			376,000
Buffalo, New York	1	19-0	250,000
	2	22-0	315,000
			565,000
Canton, Ohio	Canton	18-4	235,000
* Government owned.			

Company	Furnace indeti-fication	Hearth diameter ft-in.	Capacity net tons
Republic Steel Corporation—(continued)			
Cleveland, Ohio	1	25-6	392,000
	2	17-3	215,000
	3	17-3	210,000
	4	25-6	392,000
	*5	27-0	450,000
			1,659,000
Gadsden, Alabama	1	17-0	191,000
	*2	23-6	280,000
			471,000
Massillon, Ohio	Massillon	18-6	238,000
South Chicago, Illinois	*1	27-0	450,000
Troy, New York	1	17-6	263,000
Warren, Ohio	Trumbull-Cliffs	27-0	450,000
Youngstown, Ohio	*1	25-6	392,000
	2	24-0	350,000
	3	25-6	392,000
	4	17-9	228,000
	5	19-0	255,000
			1,617,000
Total — Republic Steel Corporation			6,324,000
Sharon Steel Corporation			
Lowellville, Ohio	Mary	13-6	174,700
Farrell, Pennsylvania	2	21-6	279,550
	3	21-6	279,550
			559,100
Total — Sharon Steel Corporation			733,800
Shenango Furnace Company			
Sharpsville, Pennsylvania	1	19-0	199,580
	3	19-6	217,720
			417,300
Sloss Sheffield Steel & Iron Company			
Birmingham, Alabama	1	15-0	145,150
	2	15-4	136,080
			281,230
North Birmingham, Alabama	3	12-8	105,240
	4	12-8	105,240
			210,480
Total —*Sloss Sheffield Steel & Iron Company			491,710
Struthers Iron & Steel Company (Pittsburgh Coke & Chemical Company)			
Struthers, Ohio	1	16-0	181,440
Tennessee Products Corporation			
Lyles, Tennessee	Wrigley	7-0	32,000
Rockdale, Tennessee	Rockdale	12-0	30,000
Rockwood, Tennessee	1	12-0	30,000
	2	12-0	30,000
			60,000
Total — Tennessee Products Corporation			122,000
Tonawanda Iron Corporation			
North Tonawanda, New York	Tona-wanda	15-6	164,200

*Government owned.

Company	Furnace identi-fication	Hearth diameter ft-in.	Capacity net tons
United States Steel Corporation			
American Steel Wire Company			
Cleveland, Ohio	B-2	18-6	244,000
	D-6	22-6	286,000
			530,000
Donora, Pennsylvania	1	18-6	225,000
	2	18-6	225,000
			450,000
Duluth, Minnesota	1	16-10	183,400
	*2	20-9	266,000
			449,400
Total — American Steel & Wire Company			1,429,400
Carnegie-Illinois Steel Corporation			
Braddock, Pennsylvania	*1	27-6	430,000
	*2	27-6	430,000
	3	26-0	410,100
	4	19-3	224,900
	5	25-0	379,400
	6	25-0	379,400
	7	25-0	379,400
	8	23-0	321,100
			2,954,300
Clairton, Pennsylvania	1	23-0	321,100
	2	18-6	207,600
	3	17-6	186,000
			714,700
Duquesne, Pennsylvania	1	19-0	219,000
	2	20-6	254,900
	3	23-0	321,100
	4	23-0	321,100
	5	20-0	242,500
	6	19-0	219,000
			1,577,600
Etna, Pennsylvania	1	17-0	181,450
	3	17-0	181,450
			362,900
Gary, Indiana	1	20-6	278,700
	2	20-6	278,700
	3	20-6	278,700
	4	20-6	278,700
	5	20-6	278,700
	6	21-3	300,100
	7	26-6	466,000
	8	25-6	432,000
	9	22-3	328,700
	10	25-0	415,000
	11	25-0	415,000
	12	25-0	415,000
			4,165,300
** Mingo Junction, Ohio	2	23-0	321,000
	3	19-3	225,800
	4	20-0	241,900
			788,900

** Not in operation by Carnegie-Illinois. Sold to Wheeling Steel Corporation.

Company	Furnace identification	Hearth diameter ft-in.	Capacity net tons
Carnegie-Illinois Steel Corporation (Continued)			
Rankin, Pennsylvania	1	22-6	321,100
	2	23-0	321,100
	3	26-0	410,100
	4	26-0	410,100
	6	23-6	335,300
	7	23-6	335,300
			2,133,000
South Chicago, Illinois	1	21-6	306,600
	2	23-0	351,100
	3	18-9	233,200
	4	25-9	440,000
	E	21-6	306,600
	5	23-0	351,100
	6	22-3	328,700
	7	18-9	233,200
	8	25-9	440,000
	9	19-3	245,900
	10	24-6	398,400
			3,634,800
Youngstown, Ohio	1	23-0	321,100
	2	25-0	379,400
	3	23-6	335,400
	4	21-0	267,300
	5	21-0	267,300
	6	21-0	267,300
			1,837,800
Total — Carnegie-Illinois Steel Corporation			18,169,300
Columbia Steel Company			
Provo, Utah	Ironton	15-9	199,200
Geneva Steel Company			
Geneva, Utah	*1	25-0	383,334
	*2	25-0	383,333
	*3	25-0	383,333
			1,150,000
Ironton, Utah	*2	22-0	300,000
Total — Geneva Steel Company			1,450,000
National Tube Company			
Lorain, Ohio	1	23-0	316,400
	2	23-3	324,000
	3	26-0	414,000
	4	26-0	414,000
	5	22-3	296,000
			1,764,400
McKeesport, Pennsylvania	1	23-0	316,400
	2	24-0	344,700
	3	22-5	300,500
	4	23-0	316,400
			1,278,000
Total — National Tube Company			3,042,400
Tennessee Coal, Iron & Railroad Company			
Ensley, Alabama	1	22-0	276,000
	2	22-6	293,200
	3	19-6	258,600
	4	22-0	276,000
	5	17-0	189,500
	6	15-0	149,100
			1,442,400

*Government owned.

Company	Furnace identification	Hearth diameter ft-in.	Capacity net tons
Tennessee Coal, Iron & Railroad Company (continued)			
Fairfield, Alabama	5	23-0	315,700
	6	23-0	315,700
	7	25-0	353,500
			984,900
Total — Tennessee Coal Iron & Railroad Company			2,427,300
Total United States Steel Corporation			26,717,600
Wheeling Steel Corporation			
Benwood, West Virginia	Riverside	19-0	234,000
Martins Ferry, Ohio	Martins Ferry	14-0	144,000
Portsmouth, Ohio	..	18-10	284,400
Steubenville, Ohio	1	21-6	306,000
	2	21-6	306,000
			612,000
Total — Wheeling Steel Corporation			1,274,400
Wickwire Spencer Steel Company			
Tonawanda, New York	X	15-0	180,000
	Y	17-6	210,000
Total — Wickwire Spencer Steel Company			390,000
Woodward Iron Company			
Woodward, Alabama	1	17-6	205,650
	2	17-0	184,150
	3	16-6	147,850
Total — Woodward Iron Company			537,650
Youngstown Sheet and Tube Company			
Campbell, Ohio	1	21-0	312,000
	2	21-6	354,000
	3	23-0	392,400
	4	23-0	392,400
			1,450,800
East Chicago, Illinois	1	18-6	294,000
	2	22-0	325,200
			619,200
Hubbard, Ohio	Hubbard	15-6	200,400
South Chicago, Illinois	3	18-6	290,400
	4	16-2	164,400
	5	18-6	229,200
			684,000
Brier Hill, Ohio	1	16-0	207,600
	2	18-6	294,000
			501,600
Total — Youngstown Sheet and Tube Company			3,456,000
Total — All United States Companies	249		70,408,300

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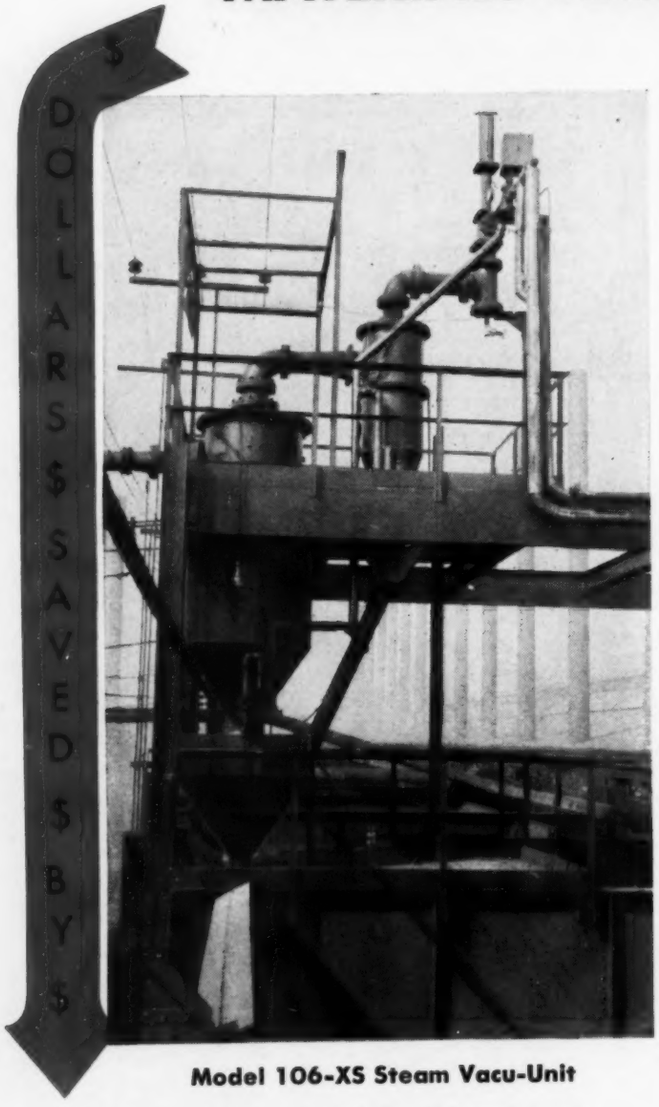

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John A. Roebling's Sons Company
Sheffield Steel Company
Standard Steel Company
Weirton Steel Company
Wheeling Steel Company
Wickwire Spencer Steel Company
Worth Steel Company

1. Removal of open hearth flue dirt direct to cars.
2. Removal of cinder below soaking pits direct to cars.
3. Removal of blast furnace flue dust from dust catchers to sintering plants or elsewhere.
4. Unload cars of bottom making materials and deliver same to suitably located bins adjacent to open hearth charging floors.
5. Unload pebble lime direct to bins for gravity discharge to slaking tanks.
6. Clean out mill scale under tables and mill drives.
7. Handle any material, not subject to caking in piping systems, in any sizes up to 4 inch diameter.

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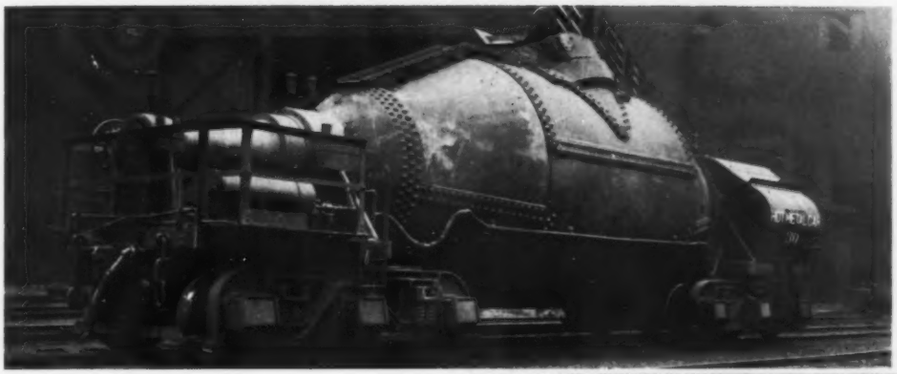

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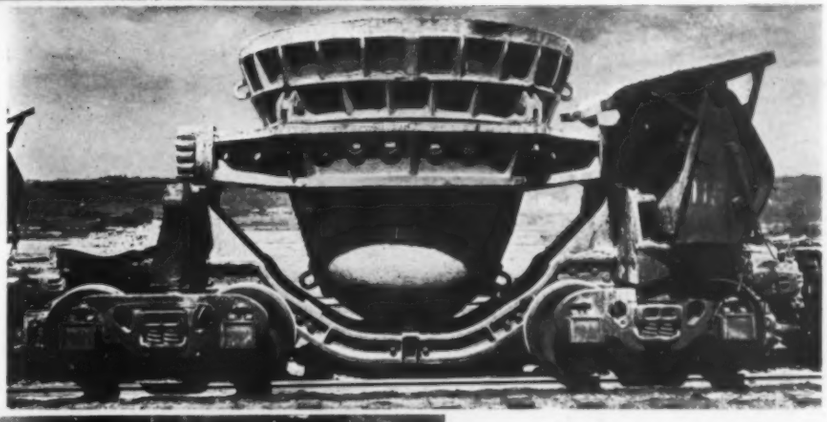

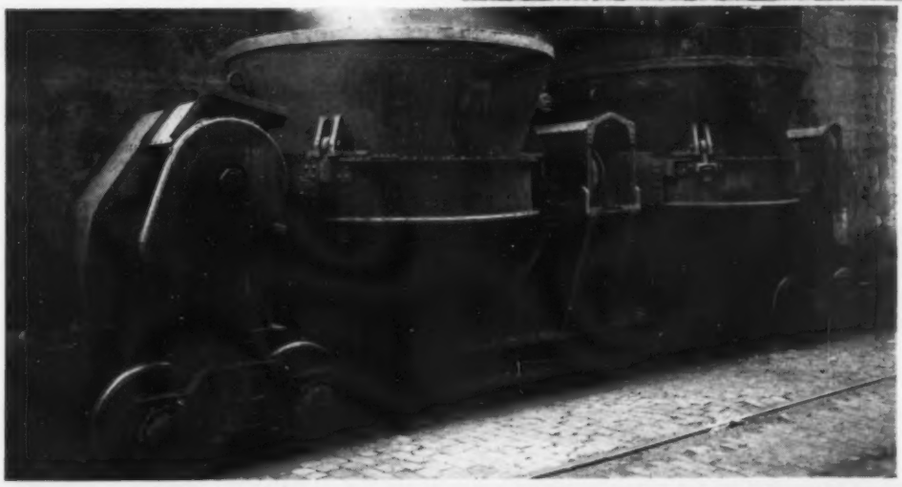

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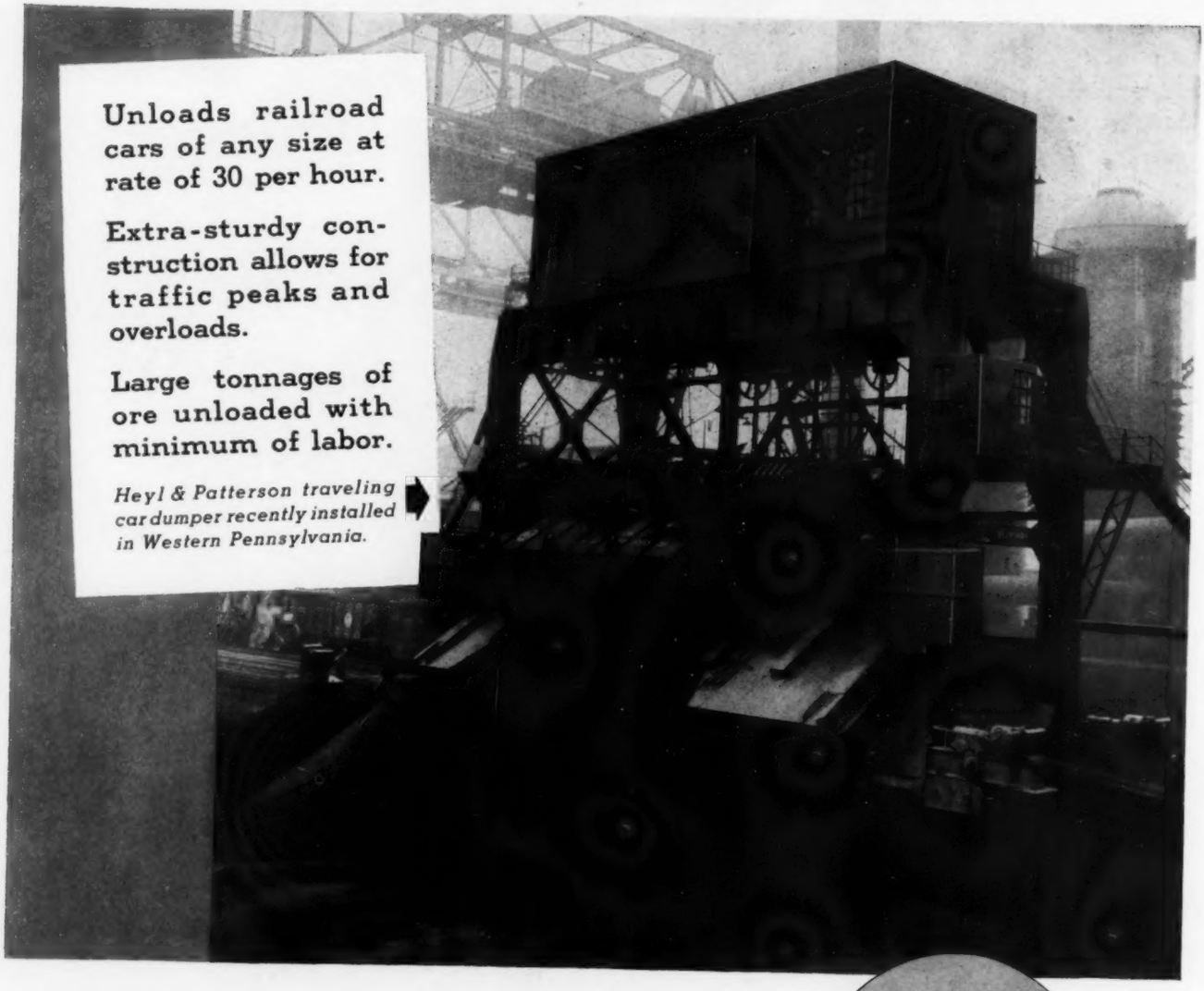
Avoid delays at your ore yard with a **modern car dumper**



Unloads railroad cars of any size at rate of 30 per hour.

Extra-sturdy construction allows for traffic peaks and overloads.

Large tonnages of ore unloaded with minimum of labor.

Heyl & Patterson traveling car dumper recently installed in Western Pennsylvania.

Thousands of tons of ore arrive each day of the lake season at inland blast furnace plants. Unless this ore is promptly unloaded and stored a serious transportation tie-up may occur.

A traveling car dumper like that pictured here handles cars of largest size, quickly dumps the ore, speeds the release of empty cars, eliminates transportation bottlenecks.

If the unloading of ore is a problem at your yard, the solution may be a modern car dumper engineered by Heyl & Patterson.

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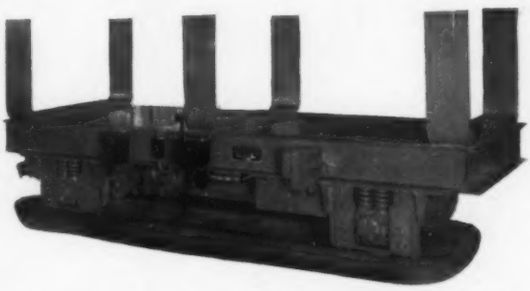
ATLAS SCALE CHARGING CARS

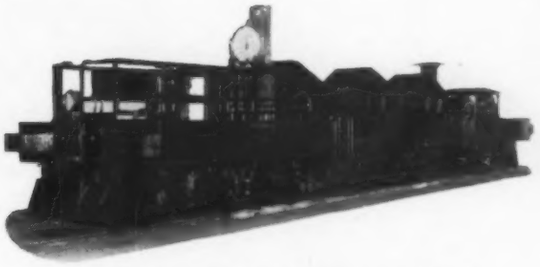
ORE TRANSFERS AND

Intraplant Haulage Equipment



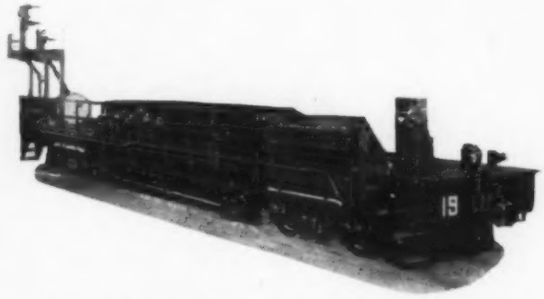
20 Ton Capacity STORAGE BATTERY FLAT CAR

For handling long bars — powered by storage battery geared to travel at walking speed when controller is held in operating position. Spring return to "off" when released — at which point magnetic brake is set.



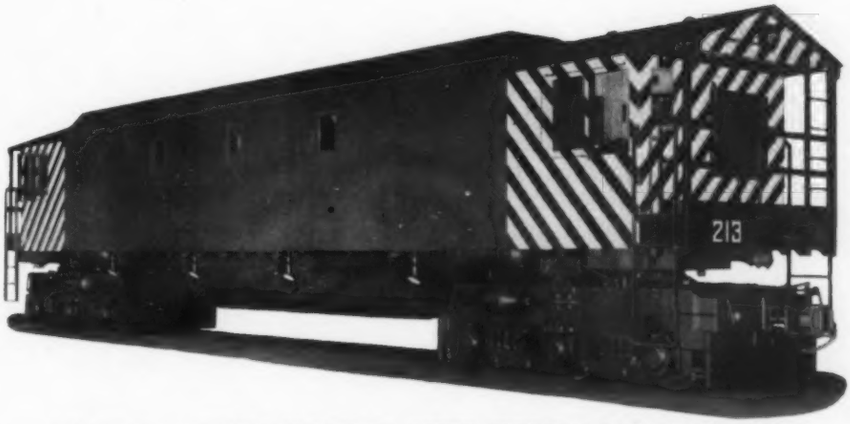
35 Ton Capacity SCALE CHARGING CAR
DOUBLE HOPPER CENTRE DUMP TYPE

Atlas Indicating and Recording Dial is provided with extra-heavy all steel roller suspension scales having removable knife edges. Also equipped with centralized lubricating system.



20 Ton Capacity BOTTOM DUMP SCALE CAR

For use with roller bin gates. Equipped with Atlas underslung roller suspension scales and Atlas Indicating Recording Dial.



110 Ton Capacity SELF PROPELLED DIESEL ELECTRIC ORE TRANSFER CAR

First self-propelled Diesel Electric Transfer. Includes double end control with tunnel through hopper permitting ready movement of operator to front end without leaving the car. Powered to permit handling trailer car of similar capacity up 3½% grade. All safety features including dead man control — interlocked discharge gates so that car can not be moved until gates are latched.

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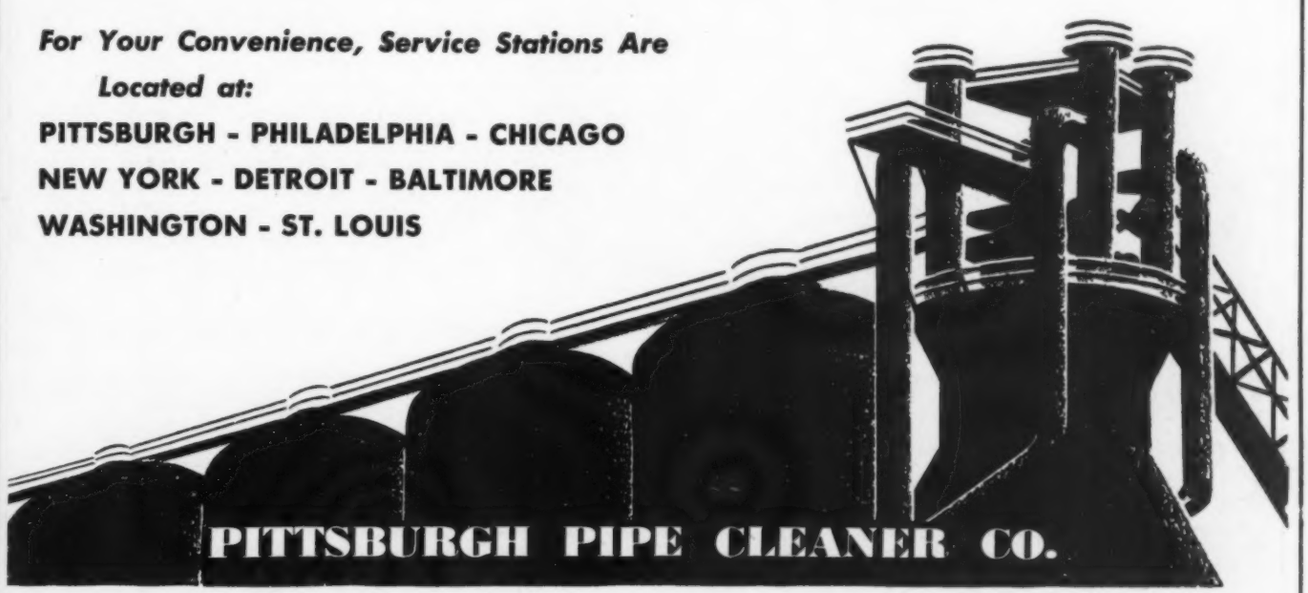


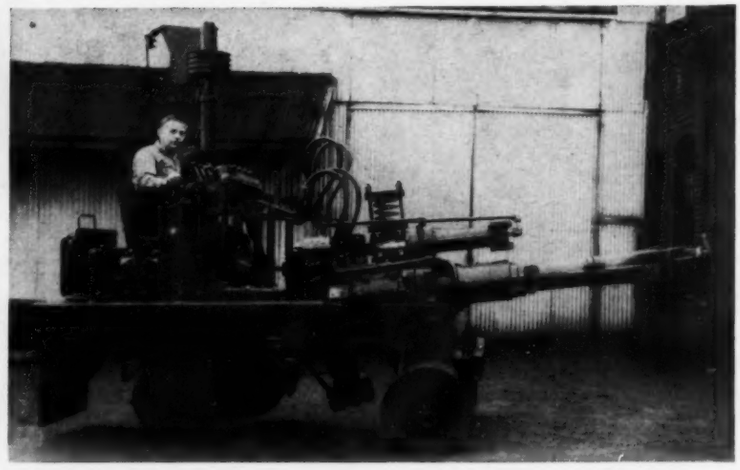
413 Melwood Street **Pittsburgh 13, Penna.**

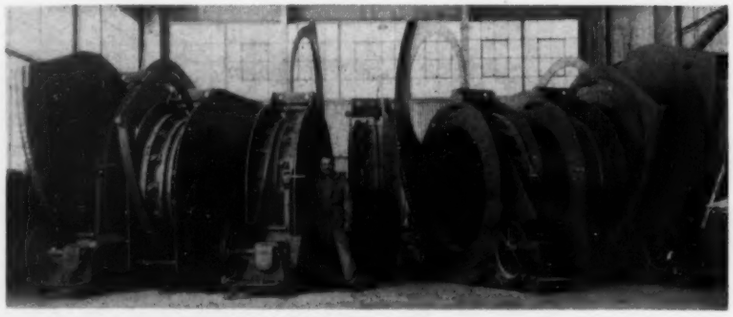
BROSIUS MODERN BLAST FURNACE EQUIPMENT

Pictured left is the Brosius Clay Gun which can be either Column or Pedestal mounted. Its operation is automatic, with all controls located at a safe distance from the tapping hole and no one needs to be in the danger zone during the plugging operation. The boom drive is positive and the gun travels into and out of the hole at a uniform speed. A non-reversing worm gear and a magnetic brake on the swing motor, eliminate the necessity of a latching mechanism.

BROSIUS COMBINATION CHARGER

The Brosius Auto Floor Charger pictured at the right is a combination tongs and box charger. The tongs head is provided with an engaging head for engaging the charging box. The machine is being used to handle miscellaneous scrap copper in a melting furnace. The scrap consists of bales, bundles, and fines — the bales and bundles being handled by the tongs, while the fine scrap is charged into the furnace from a charging box. These Auto Floor Machines are built as chargers or as manipulators in capacities from 2,000 to 20,000 pounds.





BROSIUS Goggle Valves

Brosius Goggle Valves are built to provide the highest degree of efficiency. Their method of operation minimizes the loss of gas while swinging the plate, as the flexible seats remain in light contact with the plate at all times. Separate drives are provided for swinging the plate, and for opening and closing the seats. The drive for swinging the plate can be either hand or motor operated.

WRITE FOR DESCRIPTIVE LITERATURE ON ABOVE EQUIPMENT

Write for Your Copy of Our NEW General Catalog

Brosius Equipment is covered by patents, allowed and pending, in the United States and Foreign Countries.

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Designers & Manufacturers of Special Equipment for Blast Furnaces & Steel Mills

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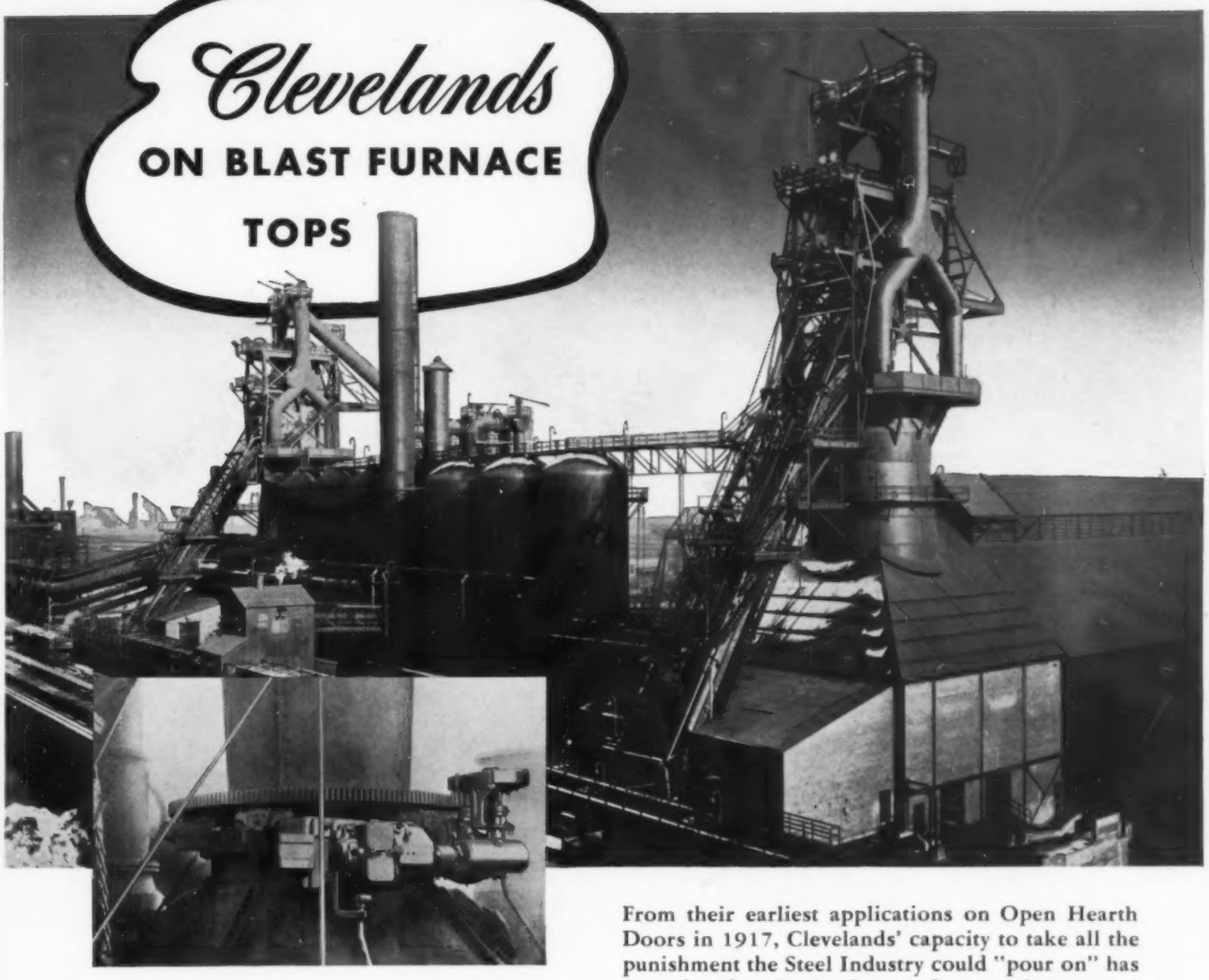
Brosius Equipment is constantly being improved to meet new and more difficult requirements of present-day production.

Clevelands
ON BLAST FURNACE TOPS



THE Cleveland Worm Gear Unit shown in the inset was designed especially for the Stock Distributor illustrated above. Its function is to rotate successive skip-loads of material, giving uniform distribution of sizes over the entire area and assuring an even draft for melting.

First utilized more than 20 years ago, this "Cleveland" application has proved so practical that installations have been made on Furnace Tops throughout the United States and in many foreign countries.

From their earliest applications on Open Hearth Doors in 1917, Clevelands' capacity to take all the punishment the Steel Industry could "pour on" has earned and maintained a good name—has created a demand totaling many thousands of installations. Clevelands today are serving on the principal items of equipment from Ore Bridges to Inspection Tables.

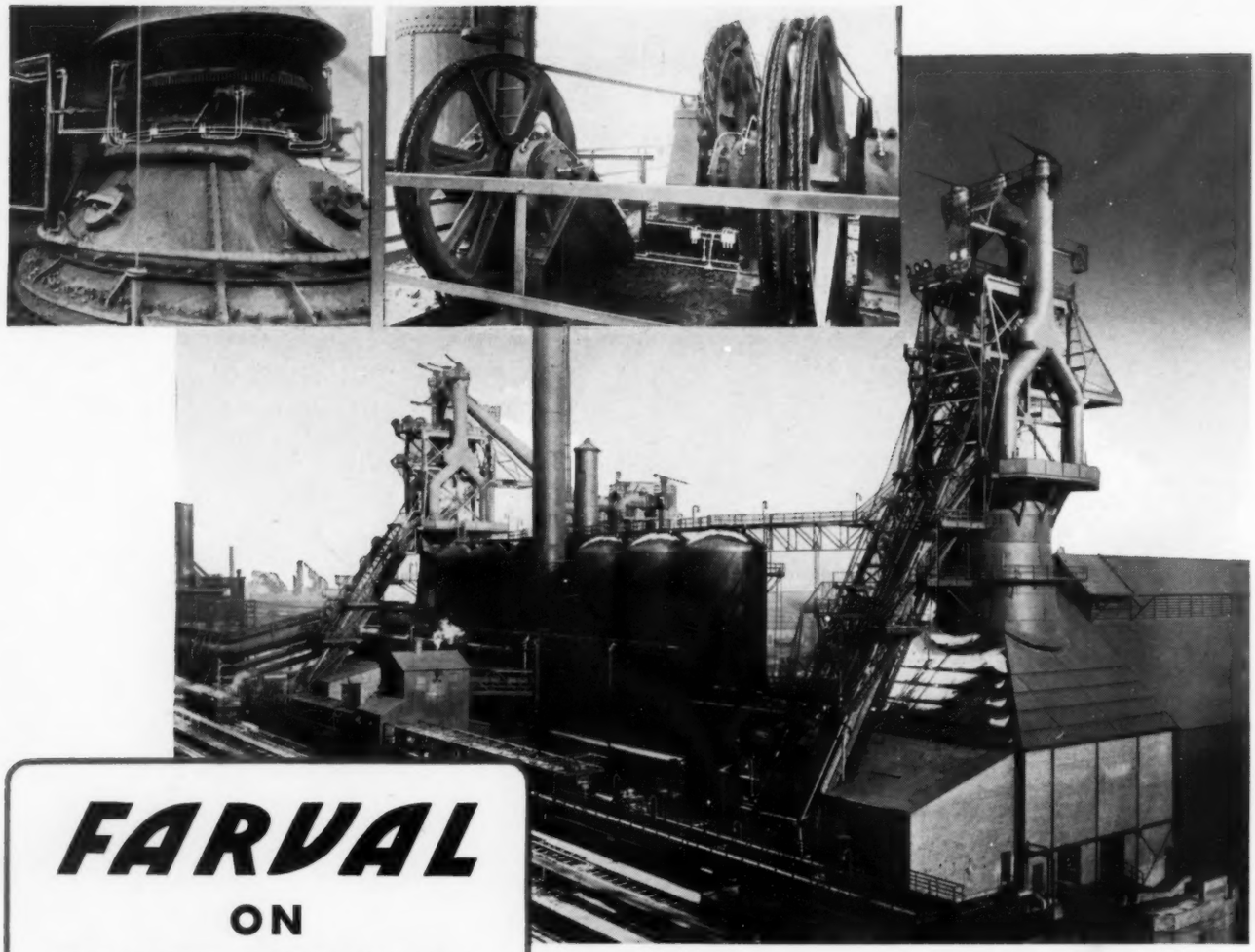
Cleveland's latest development—the new Speedaire Fan-Cooled Unit—embodies the finest of Cleveland's 34-year achievements in Worm Gearing and adds distinguished qualities of its own. Speedaire delivers *More Horsepower for your Dollar.* Full particulars upon request to your nearby "Cleveland" Representative.

The Cleveland Worm & Gear Company, 3278 East 80th St., Cleveland 4, Ohio.

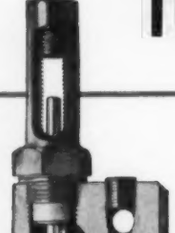
Affiliate: The Farval Corporation, Centralized Systems of Lubrication

In Canada:
PEACOCK BROTHERS LIMITED

CLEVELAND
WORM GEAR *Speed Reducers*



FARVAL
ON
BLAST FURNACE TOPS



Farval—the Dualine System with the Positive Piston Displacement Valve — that has but 2 Moving Parts—is Fully Adjustable—with a Tell-tale at each bearing to show the job is done.

It is a difficult and dangerous job to climb around on a Furnace Top to lubricate each individual bearing by hand. Many of the points on the Furnaces illustrated above are 175 to 200 feet above ground—swept by high winds and the oiler is exposed to poisonous fumes.

But with the Farval Pumping Units conveniently located in the Hoist House, the oiler on this job from one safe central point *sends* a positive measured charge of lubricant to each individual bearing—and not a bearing is missed.

The first installations of Farval Centralized Lubricating Systems on Furnace Tops were made in 1930 and today more than 50 Furnaces receive the protection and safety provided by Farval. Why risk personal injury and overlooked bearings when you can install Farval and be sure *at all times?* The Farval Corporation, 3278 East 80th Street, Cleveland 4, Ohio.

Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing

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FARVAL

CENTRALIZED SYSTEMS OF LUBRICATION

Power STEEL MAKER Modernizes Power System

. . . . plant expansions, calling for the addition of equipment to existing power systems, sometimes present a complex problem of economical power distribution . . . . how one steel plant handled the problem is described in this paper . . . .

by A. D. Howry and R. H. Wright

ELECTRICAL SUPERINTENDENT, ALAN WOOD STEEL COMPANY, CONSHOHOCKEN, PENNSYLVANIA

ENGINEER, WESTINGHOUSE ELECTRIC CORPORATION, EAST PITTSBURGH, PENNSYLVANIA

▲ THE Alan Wood Steel Company recently completed extensive changes in the power system of the Ivy Rock plant. These changes have improved the reliability of the power supply and have resulted in a marked reduction in operating costs.

As one of the pioneer iron and steel producers of the country, the Alan Wood Steel Company has used many types of power equipment. The Conshohocken Iron Works, placed in operation May 5th, 1832, by James Wood and his son Alan, had a single stand 18 in. × 36 in. sheet mill driven by a 16-ft diam water wheel. This plant was located at Conshohocken, Pennsylvania, on land lying between the Schuylkill River and the canal of the Schuylkill Navigation Company. The water wheel utilized the difference in head between the canal and the river under a contract with the navigation company for "900 square inches of water at an annual rent of $1000." The capacity of the mill was 54 sheets of shovel plate per 12 hours.

The Schuylkill Iron Works built at Conshohocken in 1857 by Alan Wood & Company used a number of engines of various types and makes until the plant was electrified in 1918. Here in 1866, Mr. Wood developed the 3-high mill for sheets and plates now in common use in many plants but known at one time as the "Conshohocken Mill."

Presented before A. I. S. E. Philadelphia District Section Meeting, December 1, 1945.

When the present steel works at Ivy Rock was first placed in operation in 1903, electric power was used to the maximum extent permitted by the electrical apparatus available at the time. Three 300 kw engine driven generators supplied 250 volt d-c power for lights, cranes and auxiliaries. A few years later when the steel works and the blast furnaces across the river were consolidated, turbo generators were installed at the blast furnaces and a-c power was made available for general use.

At the beginning of World War II the power system consisted of a steam plant for the 35 in. blooming mill, two 25 cycle turbo generators at the blast furnaces, a number of large 25 cycle induction motors, synchronous motor generators for 250 volt d-c auxiliary power, the three original 250 volt engine driven generators for standby and peak loads and miscellaneous a-c auxiliaries. A 2200 volt, 25 cycle transmission system distributed primary power to the steel works, coke plant, blast furnaces and to the Schuylkill Works.

Wartime demands had increased the load to the extent that both turbo generators were overloaded for the greater part of each day. One of the old non-condensing 300 kw engine driven generators at the steel works was being operated to relieve the load on the motor generators. It was necessary to use considerable supplementary fuel oil at the blast furnaces to compensate for variations in the quantity of gas available.

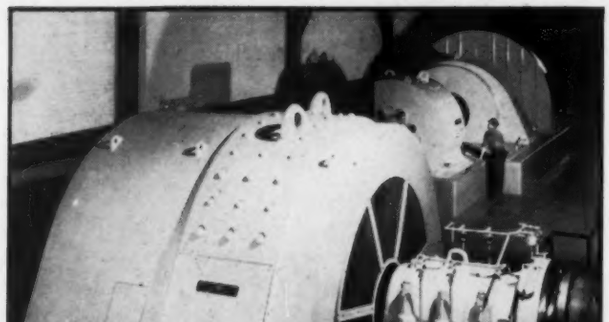


Figure 1 — New blooming mill motor room at the Alan Wood Steel Company, Conshohocken, Pennsylvania. In the foreground is a 3500 hp, 50/120 rpm reversing motor for driving the mill main rolls. Immediately behind the motor is a 3000 kw flywheel motor generator. The 6600 volt switchgear is seen at the far end of the room.

Neither new turbines nor replacement parts could be obtained under existing government regulations. Due to the age of these units, danger of partial or complete failure of a-c power was always present. The same condition existed at the 35 in. blooming mill because of the age of the engine and boilers. In order to eliminate the risk of a serious shutdown it was therefore imperative that some way be found to relieve the load on the generating system and to provide a reliable drive for the blooming mill.

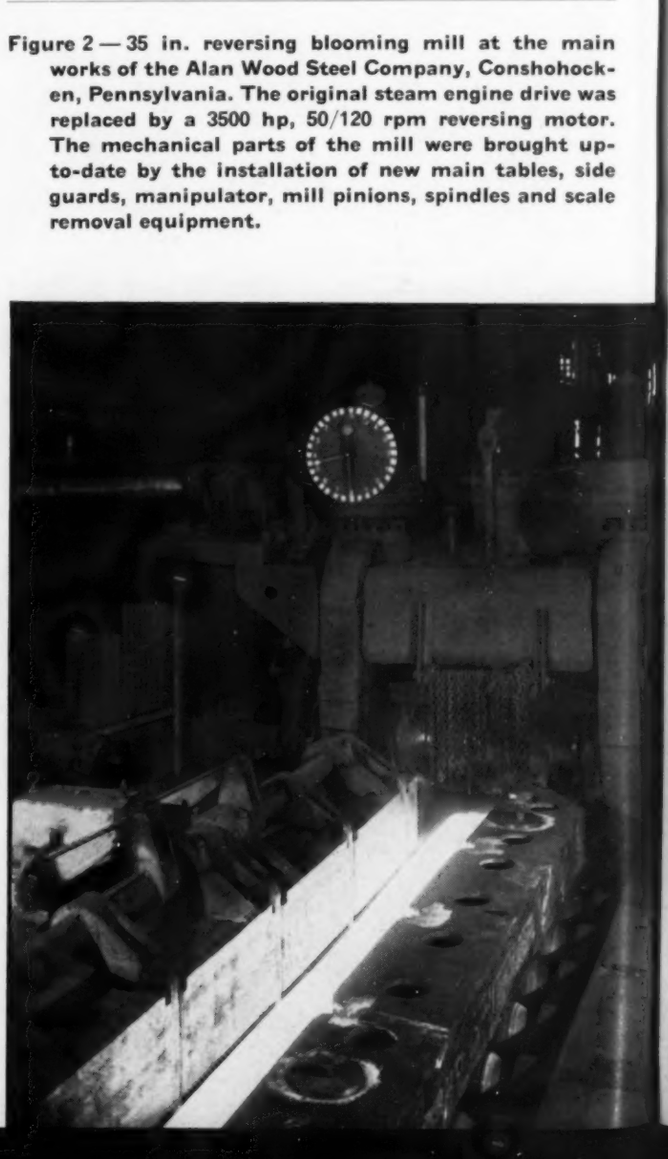
After a thorough study it was decided that the greatest improvement could be obtained by shifting some of the load to 60 cycle purchased power. This could be done by rebuilding two 1600 hp plate mill motors and providing new 60 cycle conversion equipment for part of the 250 volt, d-c load, which constitutes a considerable part of the total load. This would also provide power for electrifying the blooming mill and would form the nucleus for a gradual changeover of the entire plant to 60 cycles. With this load removed, one of the existing turbines could, if necessary, carry all the remaining 25 cycle load, thus greatly reducing the risk of complete loss of 25 cycle power. By shifting 250 volt d-c load between the 60 cycle and 25 cycle systems it would be possible to adjust the 25 cycle load to suit the amount of blast furnace gas available and reduce the amount of supplementary fuel used. The initial program including the electrification of the blooming mill has been completed. Although construction had to be done under trying conditions, the results have been very gratifying.

Power from the 33 kv lines of the Philadelphia Electric Company is stepped down to 6600 volts in a 10,000 kva outdoor substation. The secondary leads run underground to a 6600 volt metal-clad switchgear structure in the blooming mill motor room. All metering, motor control and switching of 60 cycle power is done at this point.

The blooming mill motor room, shown in Figure 1, is located in a space between the blooming mill boiler house and the mill building which had formerly been vacant. In addition to the 6600 volt switchgear, the blooming mill main drive, a variable voltage auxiliary motor generator and control; a 1000 kw, 250 volt mercury arc rectifier; a new 250 volt switchgear and a 750 kva, 440 volt auxiliary power transformer are located in this room.

The electrical equipment was installed and tried out before the blooming mill engine was dismantled. The engine was located on the opposite side of the mill so the changeover was made by moving the mill pinion stand to the side next to the motor on a new foundation, poured with the motor foundation. A new set of pinions and mill spindles had previously been provided and when the parts were in place the mill was again ready to run. A few months later new main tables, side guards and manipulator with new variable voltage drives were installed. Variable voltage control was also provided for the screwdown. Figure 2 shows the mill in operation after the mechanical and electrical changes had been made. A new air conditioned operator's pulpit, shown in Figure 3, was constructed in the plant shops complete with air, water and electrical connections, and set in place at the mill after the other construction work was finished.

Figure 2 — 35 in. reversing blooming mill at the main works of the Alan Wood Steel Company, Conshohocken, Pennsylvania. The original steam engine drive was replaced by a 3500 hp, 50/120 rpm reversing motor. The mechanical parts of the mill were brought up-to-date by the installation of new main tables, side guards, manipulator, mill pinions, spindles and scale removal equipment.



The 6600 volt switching equipment, shown in Figure 4, consists of twelve metal clad sections. One section is for metering and for remote control of the 33 kv high tension circuit breaker. The remaining sections provide control for the 6600 volt incoming cable and the circuits for the blooming mill flywheel set, auxiliary transformer, blooming mill rectifier, open hearth rectifier, two 2500 hp plate mill motors, miscellaneous light and power and for dynamic braking of the flywheel set and plate mill motors. All circuit breakers are 1200 ampere, Deion air break type with 250,000 kva rupturing capacity.

The blooming mill reversing motor is rated at 3500 hp, 50/120 rpm, 1,010,000 foot-pounds maximum circuit breaker torque. D-c variable voltage power is supplied to this motor from a 505 rpm flywheel set consisting of two 1500 kw, 700 volt generators; a 66,000 pound, 12 ft-9 in. diam steel plate flywheel and a 3000 hp induction motor.

The reversing motor and flywheel set are totally enclosed and force ventilated in a down draft non-recirculating system. Two low pressure fans deliver filtered outside air to the room and maintain a slight positive pressure in the room at all times. Exhaust fans draw air down through the reversing motor and flywheel set and discharge the heated air to an outside stack. The discharge stack and fresh air stack are located side by side and are provided with remotely controlled dampers so that the warm air and outside air can be mixed ahead of the filter in cold weather. In warm weather the brush dust from the machines is discharged outside and in cold weather it is taken out by the filter. In the warmest weather, the motor room temperature is practically the same as that of the outside air and the operators are comfortable because of the rapid air circulation.

The next item on the improvement program was the rebuilding of the plate mill motors for operation on 60 cycle power. This mill has two 84 in. three-high stands operating in tandem, one stand serving as a rougher and the other as a finisher. This is the first plate mill installation in the country to use this arrangement. Each stand was originally driven by a 1600 hp, 244 rpm, 2200 volt, 25 cycle induction motor with a 30-ton flywheel carried directly on the shaft. Using modern construction, it was possible to replace the original electrical parts with new parts good for 2500 hp, 251 rpm at 6600 volts, 60 cycles. The original shaft, base and bearings were retained without change. Figure 5 shows one of the motors after rebuilding.

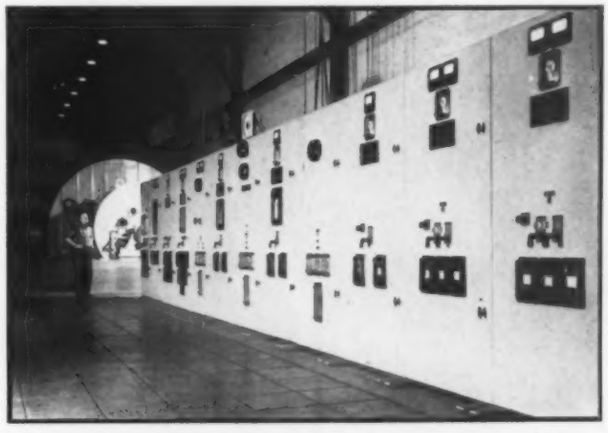
Since the plate mill motors operate at slow speed, the inherent power factor is considerably below the desired system power factor. To correct this condition, a bank of static capacitors is connected directly to the terminals of each motor. Special tests were made in the factory to determine the amount of capacitance which could be used without risk of self-excitation when the motors were disconnected from the line while idling at full speed. This precaution was necessary to prevent excessive voltage build-up while the motor was drifting to rest and to avoid the possibility of high a-c voltage being imposed on the low voltage d-c dynamic braking circuit.

The original 25 cycle motors were open type and there was no means for ventilating the motors or room.

Figure 3 — Operator's pulpit for 35 in. reversing blooming mill at the main works of the Alan Wood Steel Company, Conshohocken, Pennsylvania. This air conditioned pulpit was constructed in the Alan Wood shops, complete with electrical connection, and installed at its present location at the time the mill was electrified.

▲

Figure 4 — New blooming mill motor room at the Alan Wood Steel Company, Conshohocken, Pennsylvania. As part of a general modernization project at the Ivy Rock Plant, a 10,000 kva substation for 60 cycle purchased power was installed to supplement the plant's 25 cycle power system. 60 cycle power is distributed at 6600 volts through the metal clad, air break switchgear in the foreground. Circuits are provided to the blooming mill flywheel set in the background, to two new plate mill motors, to 250 volt rectifiers and miscellaneous light and auxiliary power circuits.



The room was always excessively warm and the capacity of the motors was reduced by recirculation of hot air. The new motors were provided with enclosing covers and chimney type frames for forced ventilation. Fans and a filter were installed to keep the room under pressure. Air from the room is forced through the machines and discharged into ducts by which the warm air can be carried outside or recirculated, depending on the outside temperature. The room now is always clean and comfortable and the motors operate with a low temperature rise.

The 250 volt d-c system at the steel works was

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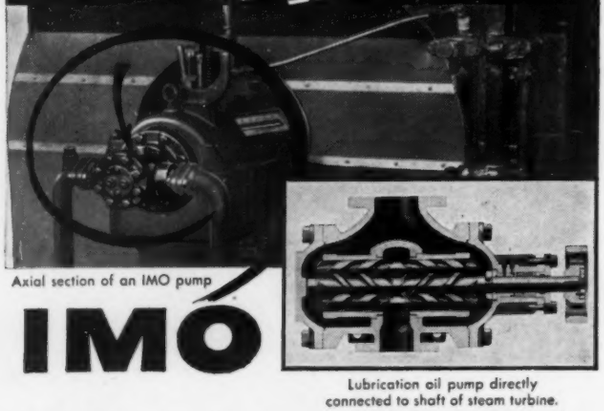

Axial section of an IMO pump

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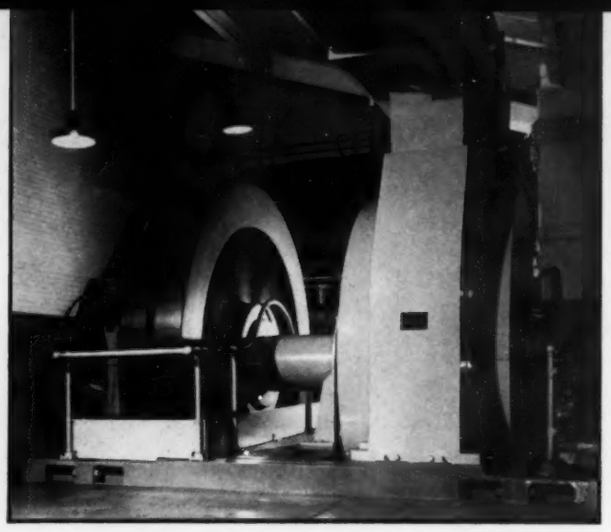


Figure 5 — One of the two 2500 hp, 6600 volt, 60 cycle wound rotor induction motors recently installed (1944) by the Alan Wood Steel Company, Conshohocken, Pennsylvania. These enclosed, forced ventilated motors, replace old 1600 hp, 25 cycle, open type motors installed in 1914 to drive the 84 in. tandem plate mill.

another item which received attention in the program. As originally laid out, the entire system was fed by synchronous motor generators located in a station near the present blooming mill motor room. The open hearth furnaces are at a considerable distance from this point and as new furnaces were added the load increased to such extent that the voltage was excessively low. To correct this condition, a 1000 kw, 60 cycle mercury arc rectifier was installed at the open hearth furnaces. A second rectifier was installed in the blooming mill motor room, both rectifiers being remotely controlled from the 6600 volt metal clad switchgear. New 250 volt switching was provided at each location. The rectifier at the blooming mill and one of the old 25 cycle motor generators are paralleled on the 250 volt d-c bus. Satisfactory parallel operation is obtained by operating the generator as a shunt machine. Load can be divided between the generator and either or both rectifiers according to the amount of power available on the 25 cycle system.

To further the economics of operation, base load units such as air compressors, river pumps, recirculating pumps, hydraulic pumps, scale removal system, and miscellaneous auxiliaries have been changed from d-c to a-c drive.

The operation of the improved power system has been very much as anticipated in the preliminary engineering studies. The new electric drives and mechanical changes for the blooming mill have made this mill a fast, smooth working unit. The efficiency of the unit is apparent when compared with the cost of steam for the engine and hydraulic system produced in inefficient, oil fired, low pressure boilers. The small engine driven generators are no longer required and have been removed. D-c line losses have been reduced to the minimum. Voltage is maintained on the entire system, giving higher speed operation of cranes and greater capacity of lifting magnets. The load on the 25 cycle generators has been reduced to a safe value and the consumption of supplementary fuel has been reduced by the ability to shift load between the 25 cycle and 60 cycle systems.

Rapid Heating OF Steels

. . . . rapid heating of steels, a trend which was accelerated by the war, is finding more and more applications . . . . the basic principles and developments upon which rapid heating depends is discussed in this paper, and a number of applications are described . . . .

by Frederic O. Hess, PRESIDENT

SELAS CORPORATION OF AMERICA

PHILADELPHIA, PENNSYLVANIA

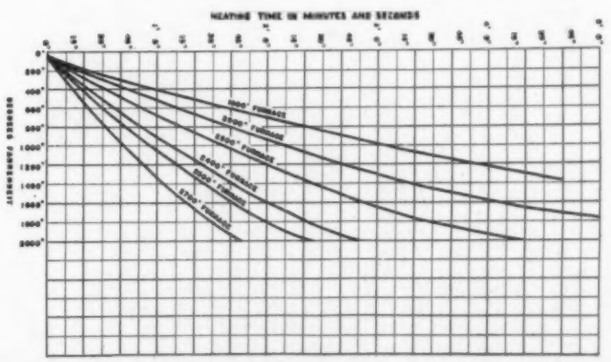
▲ DEVELOPMENTS by combustion engineers and demands of the steel industry were responsible for many changes in heat application to steel, and once again profound changes are in the making because of the principles and practices of high speed heating by means of gaseous fuels. Already so many gains in both the economics and the technology of the steel industry have resulted that it is safe to predict that ever higher speeds of heating will be a permanent trend, and not just a temporary expedient.

It is certain that simplification of plant layout and mechanics of flow of work through heat-processes, one of the by-products of high speed heating, is not an advantage to be lightly discarded now that the path to its attainment has been opened. It is certain also that the minimizing of the effects of the length of time at heat such as scale, decarbonization, etc., is another result of more rapid heating and is a matter of no small consequence; and it is certain finally that the greater control of heating uniformity, or, indeed, heat localization which results from the techniques of faster heat transfer, is a fundamental gain in the know how of the industry.

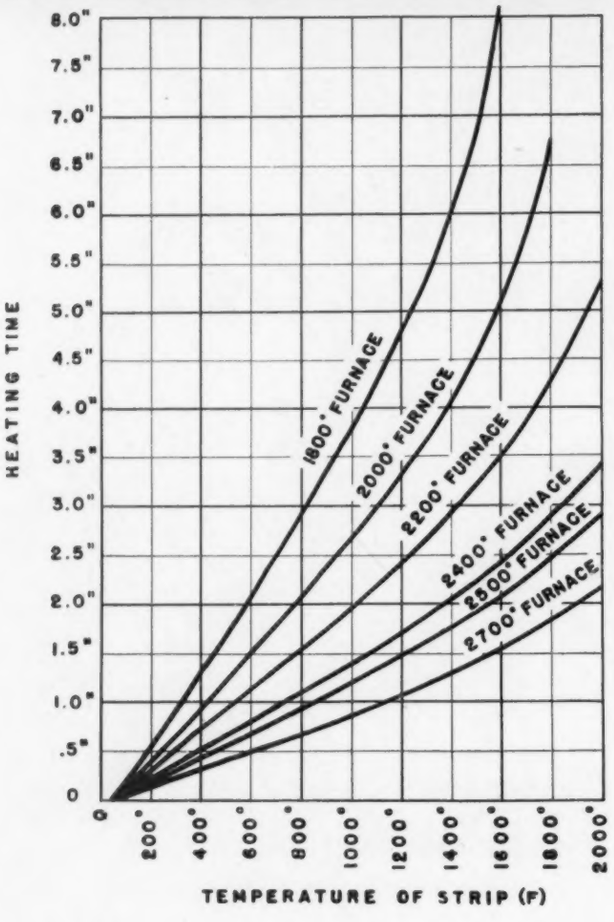
In brief, to those who have been involved in the development, it seems inevitable that the trend toward more rapid heating will not only continue, but will ultimately produce technologies which make today's efforts appear as mere beginnings.

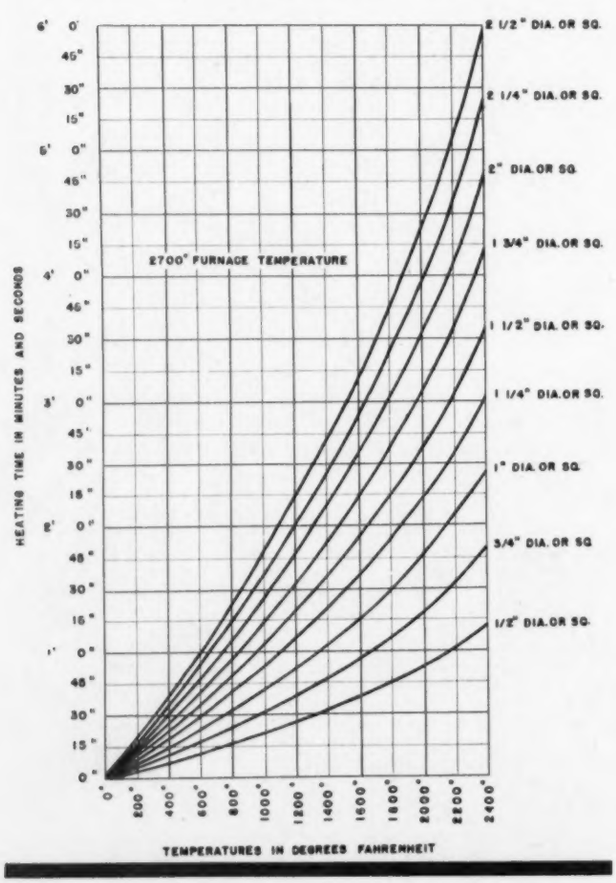
This paper is devoted to but one class of the new developments in high speed heating, that class which stems from compacting the gas-air combustion into small volumes, with a transfer of the heat to the work by means of many small, compacted combustion chambers.

Figure 1 — Vertical ordinate gives heating time in minutes and seconds for 1 in. square steel rod at various temperatures. The heating time for any other thickness rod varies directly with the thickness.



Presented before the Birmingham and Pittsburgh Sessions of the A. I. S. E. Annual Meeting, September 17 and October 8, 1945, respectively.




HEATING TIME IN MINUTES AND SECONDS
2700° FURNACE TEMPERATURE
2 1/2" DIA. OR SQ.
2 1/4" DIA. OR SQ.
2" DIA. OR SQ.
1 3/4" DIA. OR SQ.
1 1/2" DIA. OR SQ.
1 1/4" DIA. OR SQ.
1" DIA. OR SQ.
3/4" DIA. OR SQ.
1/2" DIA. OR SQ.
TEMPERATURES IN DEGREES FAHRENHEIT

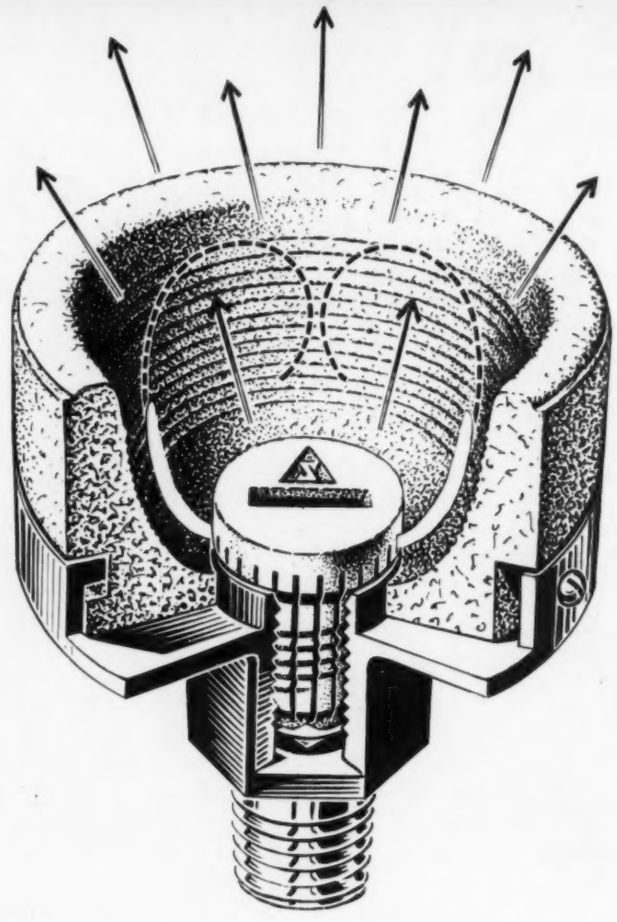


Figure 2 — Heating time in seconds for 0.010 in. thick steel strip at various temperatures. Heating time for other thicknesses varies proportionately with the thickness. (above left)

Figure 3 — Heating times for several sizes round and square steel bars at 2700 F furnace temperature. (lower left)

Figure 4 — Cut-away section of radiant type gas burner. (above right)

THE PRINCIPLES BEHIND RAPID HEATING

It has long been reasoned and known that more rapid heating could be attained if higher temperature gradients could be applied. Higher temperature of the surrounding heat source than final work temperature would accelerate many times the rate of radiation of heat from heat source to work. Radiant heat transfer varies as the difference between the fourth powers of the absolute temperatures of heat source and receiver, and small gains in "thermal head" result in surprisingly large gains in heat transfer rate.

The following Figures 1, 2 and 3, calculated according to Boltzmann's equation for heat transfer by radiation, illustrate the point. It should be borne in mind however that these calculations do not take into account convection heating nor conductivity. Figure 1 graphically

illustrates the different heating time of a 1 in. diameter steel rod when exposed to different furnace temperatures. Figure 2 shows the heating time of 0.010 in. thick steel strip when exposed to different furnace temperatures, and it can be noted that such a strip can be brought to annealing temperature in less than 2 seconds if the heat source is higher than 2500 F. A 10 ft furnace should thus permit a speed of 300 feet per minute. Figure 3 gives heating times for round and square steel bars of different dimensions when subjected to 2700 F radiating temperature.

To take advantage of these theoretical increases in heat transfer, and to make applications practical in industry, requires some fundamental steps in combustion control and construction. The radiating areas must be capable of withstanding the high temperatures and still be controllable, and the combustion reaction must be complete at all times even though large volumes of gas must necessarily be burned. If these requirements

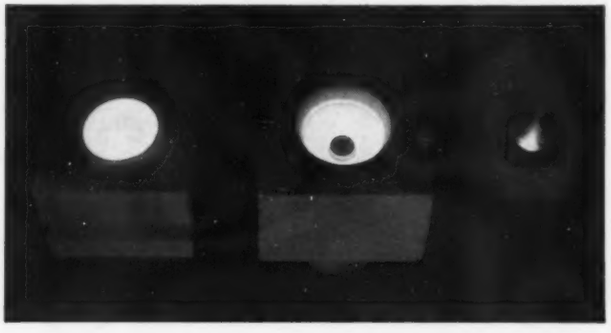
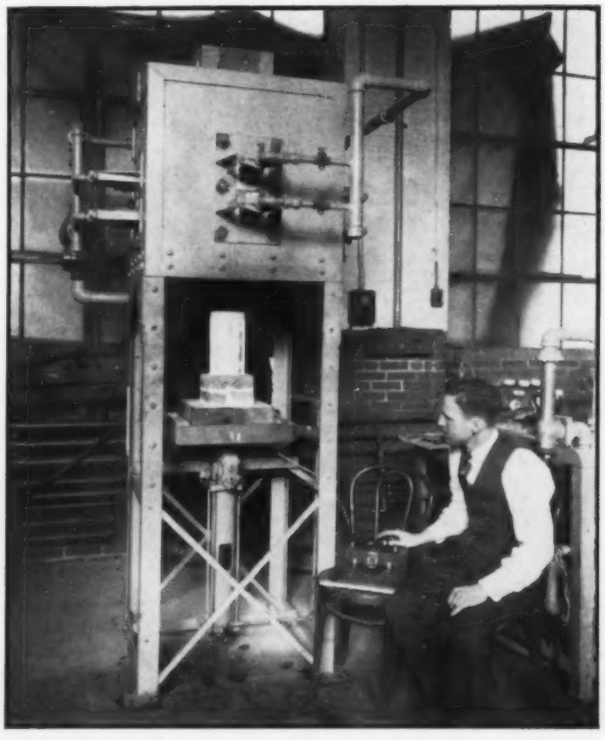


Figure 5 — Two types of radiant burners in operation. Both burners illustrate flameless characteristics of the burner.

▲

Figure 6 — Test unit for heating billets.



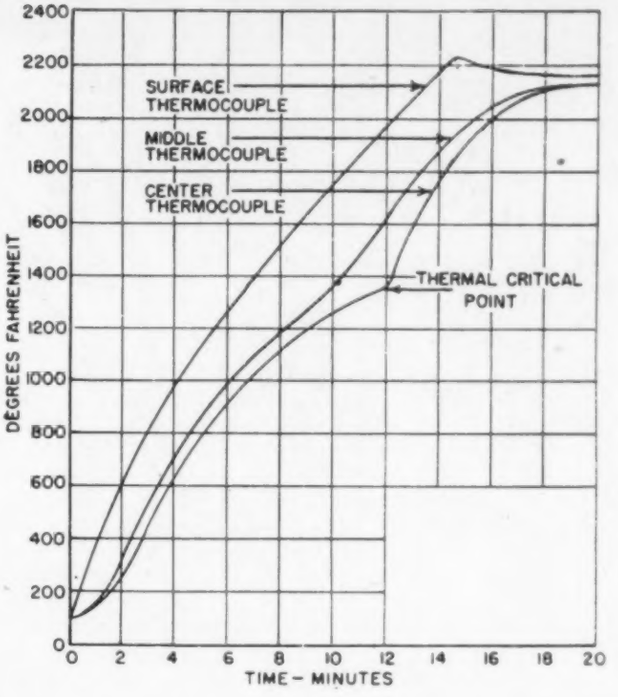


Figure 7 — Time heating curves of 5½ x 5½ in. billets.

can be fulfilled in a compacted area some basic foundations for the utilization of rapid heat transfer have been laid. These basic considerations are specifically:

1. Small combustion zones are controllable and are better capable of withstanding high temperatures, such as 2850 F or even 3100 F.
2. The combustion chambers, or radiant surfaces, which become of course actually burner elements, can be brought close to the work without the cold surface of the work disturbing the completeness of the combustion reaction.
3. A large number of high temperature radiant sources at close range means that the work pieces are exposed to a larger percentage of primary source of radiation rather than a lower temperature area of re-radiation represented by the wall area.
4. By compacting a large furnace volume into a much smaller chamber, not appreciably larger in internal dimensions than the work itself, the space between work and enclosure wall would be greatly reduced. Therefore for a given heat input and a consequent given quantity of hot products of combustion, the rate of travel of hot products past the work surface is multiplied many times. Since convected heat transfer is directly proportional to the linear velocity of the heating gases past the heated surface, convected heat transfer rates should also multiply many times.
5. An additional advantage results from the use of many burners in close proximity to the work through the ability to adjust each burner individually and thereby vary the pattern or distribution of heat transfer rate over the work surface. Thus unequal heat losses from different parts of a work piece can

Figure 8 — Photomicrograph of billet after rapid heating showing small amount of decarburization and scale.

be compensated for to attain uniform rates of temperature rise over the surface of irregular work, or with the opposite objective, selected regions of the work piece may be heated to higher temperatures than others.

The question of course is how to manipulate the combustion reactions and how to design carbureting equipment and radiating elements, or burners which permit such new types of heating units.

COMBUSTION SYSTEM DESIGNS NECESSARY FOR RAPID HEATING

The attainment of combustion of the type described rests upon four factors:

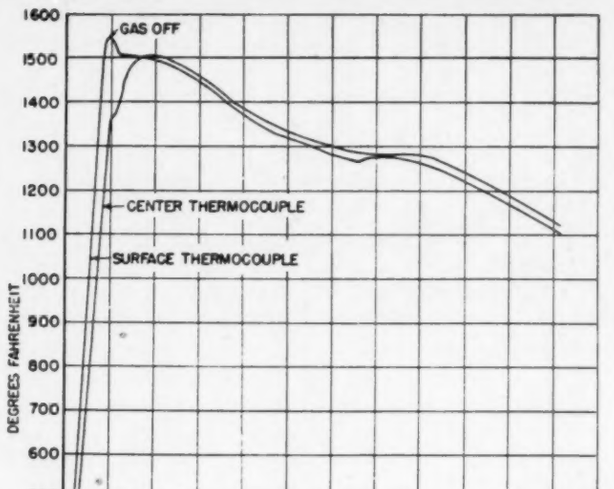
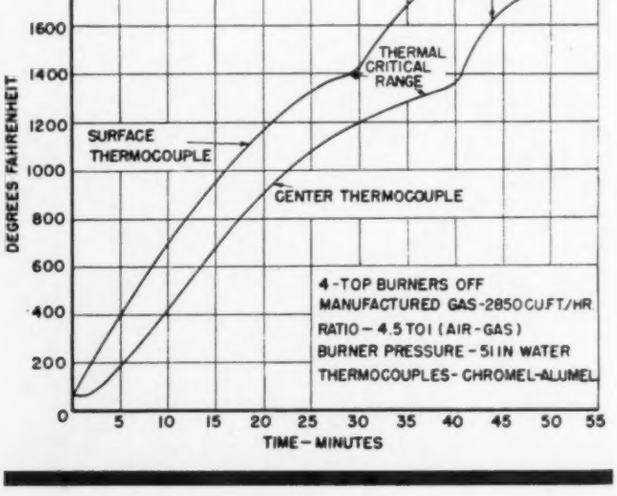


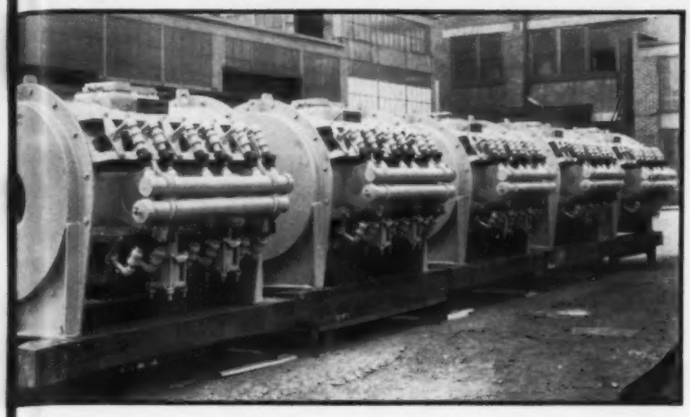
Figure 9 — Rapid heating curves of 2 x 2 in. billet.

1. Precise and automatic carburetion of gas and air in such a manner that the air-fuel ratio supplied to any burner remains constant irrespective of any changes in total gas consumption, the adjustment of any burner or burners, inlet gas pressure or other variable factors.
2. The delivery of this carbureted fuel to each burner at pressures in excess of conventional burner pressures or up to 3 psi.

Figure 10 — Heating of large crankshaft prior to twisting.

Figure 11 — Heating curves of crankshaft shown in Figure 10.





3. The design of the burner elements and distribution of the burner ports in such a manner that the combustion reaction is completed over a wide capacity range and flame lengths held to a minimum. This means, among other things, many small burner ports which, coupled with a high mixture pressure, allow the wide fuel input range or operating range required.
4. The extensive use of specialized ceramics as basic elements of burner construction, in the interest of durability, at temperatures beyond the range of metallic materials. Dimensional accuracy in burner and ceramic construction of an order not common in burner design and refractory properties which will permit burner surfaces to attain and to be maintained at high degrees of incandescence and which respond rapidly to changes in fuel input.

Both items 1 and 2 are achieved through the use of carburetion equipment incorporating compressors, which has long been available but has only in recent years been considered essential for heavy but nevertheless precise heating operations.

Factors 3 and 4 are satisfied only through the development of an entirely new technology of burner construction, which factor is the basis of this discussion.

Perhaps the most typical burner construction so far developed is that shown in Figure 4, popularly known as the "radiant" gas burners. Precarbureted gas and air, or a pre-mixture, is delivered under pressure centrally at the bottom of the cup and projected through small burner ports along the cup surface. Thus combustion proceeds from the center toward the rim of the burner cavity. The burner cup surface attains incandescent temperatures, holds the combustion reaction entirely within the burner cavity and eliminates that blasting or torching of flame which is characteristic of all single port burners however designed. The burner is flameless in the conventional sense.

Figure 5 shows 2 such burners of different design operating at the same rate of gas consumption and on the same manifold as a conventional tunnel type single port burner. The intensity and uniformity of the radiation and the absence of flame beyond the burner face is apparent.

THE GEOMETRY OF BURNER APPLICATION

Let us now consider the various shapes of burner enclosures which might be and are employed around various classes of work.

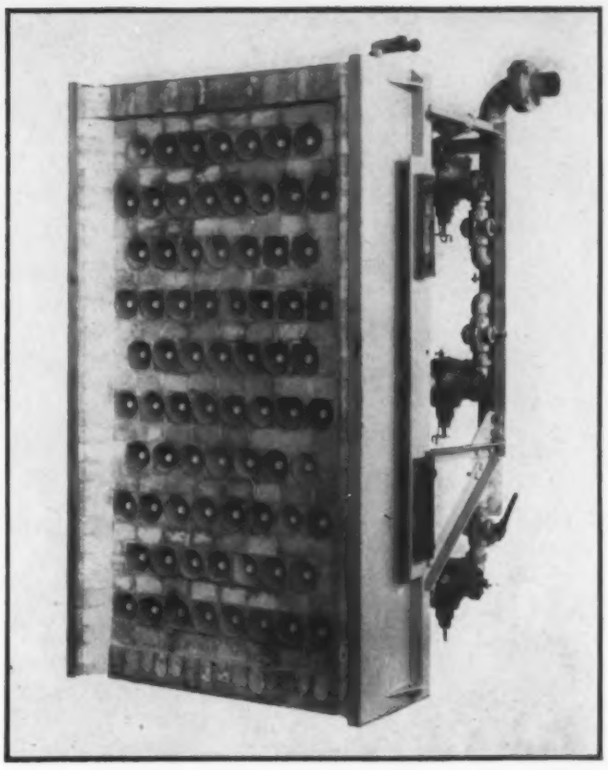
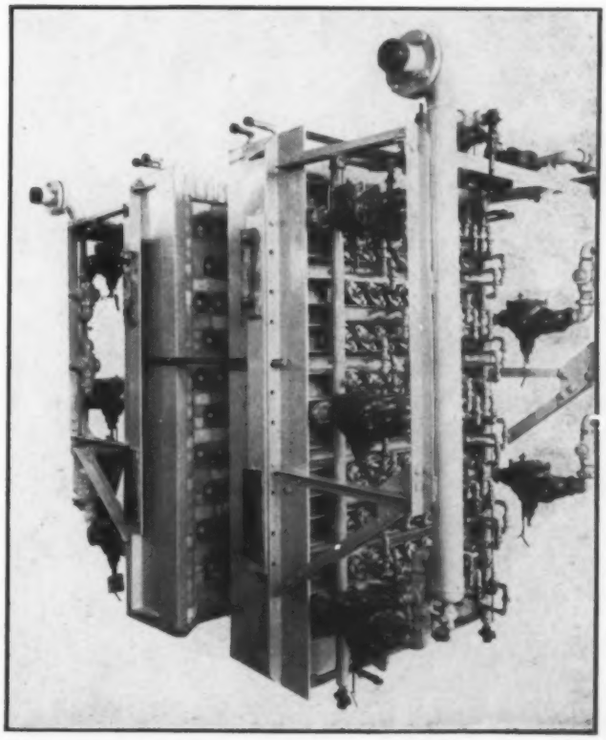


Figure 12 — Furnace used for annealing or heat treating seamless tubing, rod stock, and stainless steel tubing. (above left)

Figure 13 — Heating panel used for electrolytic tin plate in a western steel mill. (above right)

Figure 14 — Back view of panel shown in Figure 13. (below)



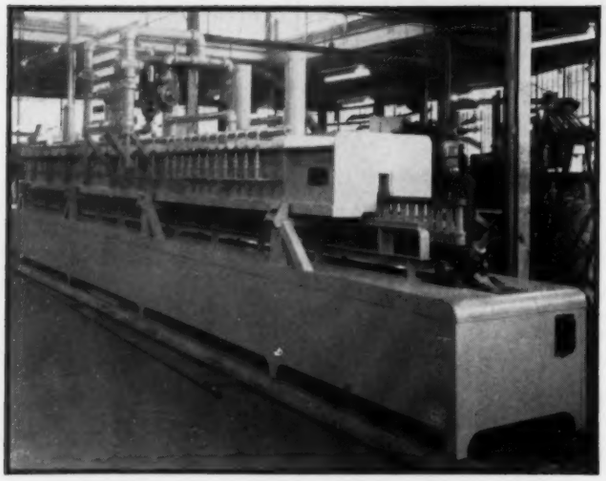


Figure 15 — Overall view of heating unit to process anneal heavy mortar shell.

▲

Figure 16 — Closeup view of furnace for annealing heavy mortar shell.

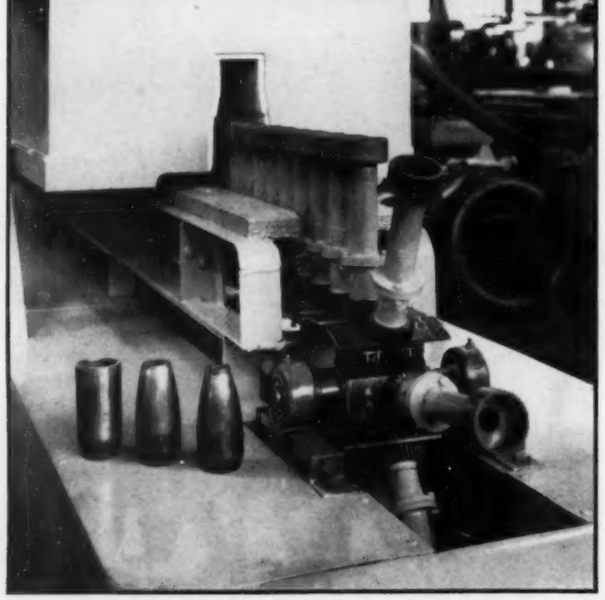
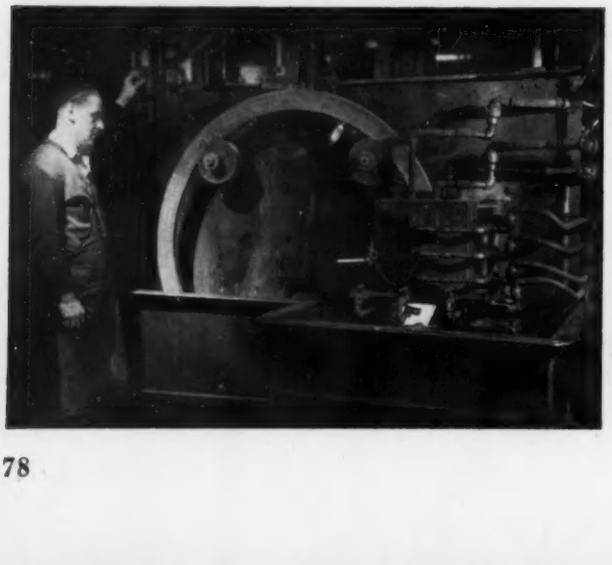


Figure 17 — View of large ball race in heating furnace.



Radiant burners studding the walls of a small bell can be made to virtually enclose large, chunky billets. With the burners arranged in a horizontal sleeve a complete cylindrical enclosure adaptable for continuous heating of rods, tubes, or bars is the result. For traveling strip, opposed flat panels, each composed of solid banks of burners, provide another geometry of enclosure of moving work. Individual pieces in single file, supported from the bottom or hanging from a conveyor, may pass through tunnels constructed of 2 opposing burner walls. Furnace roofs composed almost wholly of burners and spaced within a few inches of the work further extend the design and construction possibilities. All of these, and many other different arrangements, have found successful and surprising uses within the last few years.

APPLICATIONS

The versatilities and capabilities of this heating logic may be evaluated through the following installations:

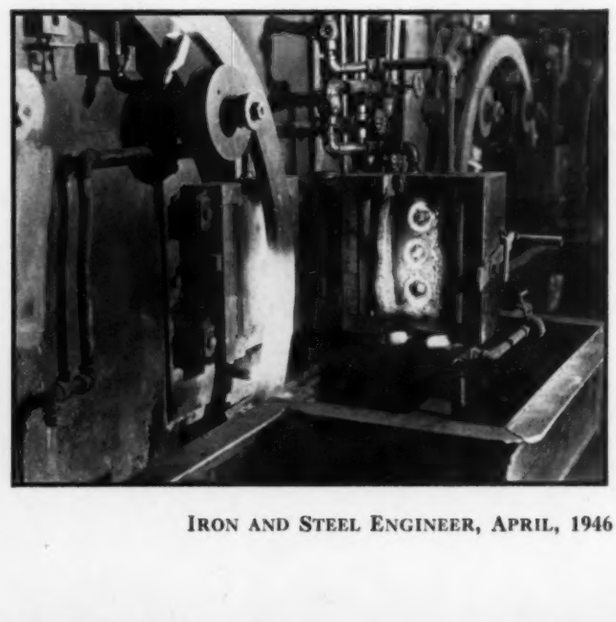
Figure 6 shows a test unit for heating 6 in. round or square steel billets, and the curves in Figure 7 give one heating result. Note that a billet of one of the so-called tender steels, SAE 4340, measuring $5\frac{1}{2} \times 5\frac{1}{2} \times 10$ in. was heated in this compact unit to forging temperature within 18 minutes.

Observe also the photomicrograph in Figure 8 made at the surface of the billet after such heating, which shows no more than 0.001 in. of decarburization and negligible scale. Even this amount of scale, it can be shown, was predominantly developed during the cooling cycle in contact with air.

Figure 9 shows a heating curve in a similar test furnace of a 2×2 in. square billet which was brought up to 1500 F in 4 minutes, or at a heating rate of 2 minutes per square inch. It should be noted that this heating rate is so rapid, both on the surface and the center of the billet, that the thermal critical zone is not recorded by the instruments, but it is very apparent on the cooling cycle.

Figure 10 shows a test on a 3200 lb crankshaft, a

Figure 18 — View of large ball race in heating furnace with burner door open.



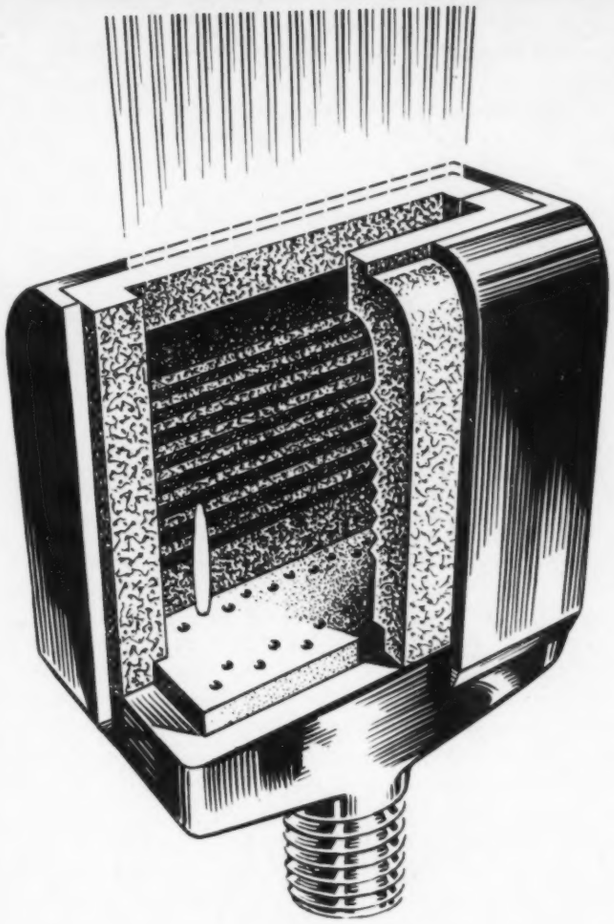


Figure 19 — Another type ceramic burner used for rapid heating.

single journal and part of the throwblock on either side being heated for twisting to 1800 F in approximately 45 minutes. The minimum diameter of the journal was 9 in. and the nonmachined throws measure 10 × 15½ × 12 in. each. The localization of heat, in spite of the mass involved, is noteworthy. The heating curve for this crankshaft is shown in Figure 11.

Units of the type shown in Figure 12 have been used for annealing seamless tubing, hardening and drawing solid rod stock, and heat treating stainless steel tubing at continuous lineal speeds up to 40 fpm. The heating cells are purposely kept short for structural reasons and to permit installation of the supporting roller equipment external to the furnace. This type of continuous heat treatment not only insures minimum times under heat, generally a matter of seconds and never in excess of a few minutes, but it also insures that every section of every length, and every length in the production run follows precisely the same path, through the same cell for precisely the same heat treatment. There is no difference in time at temperature from one bar to the next. Nor is there a difference in time interval between heat and quench.

The units shown in Figures 13 and 14 are panels of the type employed in flowing electrolytic tin plate in a western steel mill, at a production rate of 600 fpm on strip up to 36 in. wide. All radiant burners are individually adjustable to compensate for unequal heat losses at the edges and at the center. Modulation of heating effect with strip speed is accomplished rapidly by automatically moving the radiant gas panels either nearer to or further from the traveling work. Similar panels can be employed for heating strip steel for annealing purposes, or preheating it for pickling, galvanizing, etc.

The unit shown in Figures 15 and 16 was originally designed for process anneals on heavy mortar shells between successive press operations. Only the section requiring annealing was heated in single file at a rate of 1000 pieces per hour. Observe the burners on the side walls of the tunnel are more frequent at the entrance end of the unit to provide a speedy heat-up, and more widely spaced elsewhere to satisfy a pre-determined and specified holding cycle at temperature.

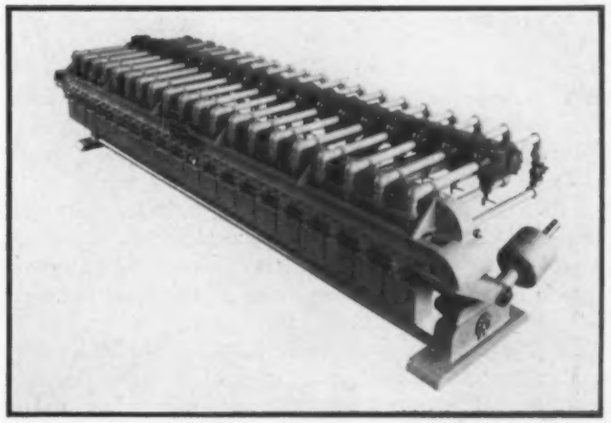
Figures 17 and 18 illustrate an interesting continuous heat treating application, namely: the hardening and drawing of large ball races. The races have a cross section of 4 in. × 1¾ in. Full hardness had to be obtained throughout the section, and continuous operation permitted a reduction in distortion previously obtained when the rings were heated all over and then hardened by an overall quench. The 6 burner hardening unit, having 3 burners on each side, permitted a production speed of about 3 in. per minute, and the draw burner was coordinated with this speed.

Figure 19 shows another class of all-ceramic burner used for the rapid heating of materials. Here the combustion is enclosed wholly within the ceramic cell and the hot products of combustion are exhausted against the work at high velocity through narrow outlets.

Figure 20 shows a unit incorporating 20 burners similar to that in Figure 19, mounted end to end, which is continuously heating pipe prior to the final welding operation at a production rate in excess of 100 fpm. The equipment is so designed that it is automatically thrown out of heating position if the process is stopped for any reason. Almost identical equipment has been applied to the high speed anneal of the welded seam of electric welded tubing.

The above examples have shown briefly, typical rapid heating applications, which are but a few of the many possibilities. The implications of such heating rates and

Figure 20 — Second type rapid heating burner used in a battery of 20 burners for continuous heating of pipe.



equipment are enormous. The classes of work involved vary from fine wire to alloy steel plates of over 50 tons each. As may be expected with any new development, in some instances technical and control problems arise in connection with rapid heating applications, which require extensive engineering and cooperative work. For example, the handling of materials often requires new methods to suit these rapid heating rates and heat treating operations. The difficulty of measuring temperatures of traveling work pieces, in many cases, has given way to controlling operating conditions, such as fuel input and speed, to a standard, previously established as producing the desired result. Such problems can and are being solved gradually by application, cooperation and study, and therefore no one can predict, at this stage, how completely such high speed heating techniques might reshape the heat-processing habits of the steel plants.

DISCUSSION

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E. A. HAWK, Fuel Engineer, Tennessee Coal, Iron and Railroad Company, Ensley, Alabama

J. L. MILLER, Assistant Chief Combustion Engineer, Republic Steel Corporation, Cleveland, Ohio

W. N. HORKO, Engineering Department, Henry Disston & Sons, Inc., Philadelphia, Pennsylvania

M. K. MORRIS, Field Engineer, Combustion Department, Bethlehem Steel Company, Bethlehem, Pennsylvania

A. J. FISHER, Fuel Engineer, Bethlehem Steel Company, Sparrows Point, Maryland

A. W. C. SMITH, Chief Engineer, Phoenix Iron Company, Phoenixville, Pennsylvania

W. Trinks: The slits in the burners must by necessity be very narrow. If the fuel gas is dirty, they will be clogged up. In most of the steel plants, coke oven gas is not cleaned very well. Mr. Hess could perhaps tell us what his experience with coke oven gas has been in the radiant cup furnaces. The second item upon which enlightenment is needed is the question of soaking. Rapid gas heating is comparable to induction heating at high frequency. The outside of the bar becomes extremely hot while the center is still cool. What provisions are made to turn the gas off at the right moment so that the proper soaking heat is produced?

The third item I wish to bring up is this. The new heating system which Mr. Hess propounds is particularly applicable to mass production of objects having the same size, day after day. I once recommended the Selas system to one of my clients, but he rejected it on the grounds that he heats square plates from 4 × 4 inches to 8 × 8 inches. If these plates are stacked up vertically in the furnace, the guiding would be poor for the 4 × 4 inches, and the distance from the burners to the surface to be heated would be too great. In consequence, my friend went back to the old type furnace, which had been in use in his facility for many years.

F. O. Hess: It is very true that dirty gas is detrimental to performance. We don't apologize for this condition, but feel that dirty gas just should not be used. This restriction may limit operations at this time, but, eventually, many operations will have to be refined and, I believe, the cleaning of gas will be one of these refinements.

Further, we will have to make provisions for soaking. On strip and small bars it is not essential. We cannot create a temperature differential in thin strip, but with 1-inch, 1½-inch, and 2-inch bars, a soaking section becomes necessary. The time for balance of temperatures between surface and center depends, of course, on the size.

Professor Trinks' comments on the application of fast heating are very true. Fast heating does a much better job on uniform sections than on non-uniform sections, if the entire section has to be heated. There are cases, however, where the quantity involved makes a great deal of difference. The automobile axle, for instance, is different in section, but, because of the quantity involved, we can devise units for heating them, concentrating heat on the heavier section, spreading the heat thinly on the smaller section, and bringing both sections to the proper temperature at the same time. The equipment then offers advantages for high production rates.

H. T. Watts: The highly developed process, just described, has evidently been a great boon to those engaged in the heating of smaller sections. It is to be hoped, and there appears a probability, that the same process may be applied to the heating of larger sections, such as slabs and billets. As such, it could relieve the present type continuous furnace of some of the functions with which it is now encumbered, and leave it free to properly perform its principle function, that of transmitting heat to the stock under conditions most favorable to quality, economy, and producing rate.

Of course, we have reference to the fact that in the continuous furnace of the present day, there occurs the mixing of fuel and air, the process of combustion and the heat transmission. These functions are to a great extent interdependent, and near perfection in any one of them may perforce be attained only at the expense of less satisfactory results in either or both of the others. It is interesting to note that in the process described, the proportioning, the mixing and the combustion process are completed before the combustion gases enter the furnace. The furnaces therefore receive only steel and inert gases, the latter carrying only the heat required for dissipation to the stock.

By operation of a multiplicity of these systems, each temperature controlled, it should be possible to cause the stock in a continuous furnace to absorb heat in each section at the maximum rate at which it can gracefully receive it in each section. Naturally, in order to avoid difficulties, it would be necessary to remove waste gases

from each section to prevent influence of those from one location upon the temperature of gases in another location. This would involve high heat losses from those sections near the end from which the steel is discharged, except that recuperators would be installed to return a generous fraction of this loss to the air before it enters the process of combustion.

By this means, it would appear possible to greatly accelerate the heat absorption by the steel in the first portion of its travel through the furnace and decrease the transfer of heat in the section near the steel discharge point. Such procedure should greatly increase the production per square foot of bottom area, and if this can be accomplished with economy in use of fuel, it will constitute a great improvement in present day heating of slabs and billets in the orthodox continuous furnace. In these, only a small quantity of heat is delivered to the steel at the entry section where, because of its low temperature, the steel has the greatest capacity to receive it; rather, main dependence for heat transfer is placed upon the forward section of the furnace.

E. A. Hawk: To obtain a burner mixture pressure of two to three pounds per square inch, as stated by Mr. Hess, requires a carburetor to proportion the air and gas, and a booster.

In conveying the explosive mixture, safety devices are necessary, such as fire-checks or screens to dampen the effect of a back-fire that may occur. These checks must be cleaned periodically to prevent excessive pressure drops throughout the system. Most carburetors are equipped with dry filters for cleaning the air.

While the gas temperature may be fairly constant, the temperature of the air may vary 20 to 30 degrees F between the day and night. This change in air temperature causes variations in the proportioning of air and gas of about two to three per cent. Some carburetors are equipped with monitors or governors to correct for variations in proportioning. Wet cleaning the air provides two additional advantages in that it helps to maintain a more constant air temperature to aid in proportioning, and does not have the build-up in resistance which is characteristic of the dry filter. When accurate proportioning is essential, clean air at constant temperature should be given careful consideration.

F. O. Hess: Carburetion equipment does require additional control, and these large scale installations brought us face to face with the problem.

We had six inches of solid metal to penetrate in the hardening of the 6-inch shell cap and found that we could harden at a certain time cycle in the daytime but not at night, nor on humid days. The problem was solved with complete air conditioning of the combustion air. That is expensive, but did not make much difference on a war job. Recent tests reveal that full automatic correction has been applied.

Simplified methods for cleaning both the air and the gas will have to be devised. We are working on it right now.

I believe that present carburetion equipment is obsolete for such large installations, but we haven't anything to substitute for it so far. Additional equipment will have to be designed and built, particularly for work on slabs. We have our eyes on the slab mill and the billet mill, and are looking at some of these operations, strictly and selfishly from a heating standpoint. What is the best way to heat a slab? Automatically, we say, and from both sides, not just from the top. We prefer to stand the slab on edge, for we don't like the idea of putting burner equipment underneath. However, at this time, there are very few fuel engineers in slab and billet mills who are willing to take the risk of standing the slab on edge.

J. L. Miller: I know of one furnace under construction at the present time designed to heat stainless steel bars 1½ in. in diameter to a temperature of 2100 F and at a speed through the furnace of about 3 ft per minute. This furnace will take a range of from ¾ in. bars to 3 in. The complete installation is made up of a series of heating units in tandem similar to the single unit which Mr. Hess has described and shown to you. The temperature and speed control are to be automatic.

Continuous billet reheating furnaces have been trying to practice high speed heating by operating at higher heat heads for some time, and in many cases doing excellent work in temperature with nominal sacrifice of fuel return.

I believe someday probably not too far in the future, this means of firing will be applied to continuous weld tube furnaces and possibly continuous annealing of coiled strip.

F. O. Hess: Control is still very much of a problem. We have worked on it and are using the only instrument which is, at the present, available. However, it is not a cure-all, and it is not the final answer. The complexity of the problem can best be illustrated with the reminder that the slightest variation of the surface of the steel will cause a difference in temperature readings.

On one particular operation which had a speed of about 10 feet per minute — we have recorded temperature variations of more than 200 F within a space of only 6 inches, and we know that we could not produce such variations with the equipment used. Since it was the surface conditions of the steel that caused the variations, there is only one way to attack the problem, apply these heating techniques, and determine in practice the cause of the variations and correct for them until someone develops an instrument for correctly measuring temperatures on continually moving pieces.

In the installation of which Mr. Miller speaks, we are using the radiation instrument as well as controlling the speed of the work electronically, because we want to operate as fast as we can. With normal work-flow, a reaction time of 45 or even 30 seconds is too slow; we have to work much faster. We can control speed today but we cannot automatically compensate for the surface variations, consequently, there is still room for a lot of work on the subject of temperature measurement and control.

The same problem applies to the handling of heavy bar stock in order to match present day mill production, and there is no question about it being a tough one. I doubt very much if this will be done on a continuous basis — some other means will have to be devised.

We are toying right now with the idea, on one particular job, of heating billets between two walls. There, usually, are two reactions to such a proposition, "the

billets stick together" or "no they don't." I don't think we will ever find the answer until we try it.

W. N. Horko: In furnaces having such high temperatures and where work is flash heated how would an operator know when his work has reached a predetermined temperature? Is it done with a radiation type instrument? In a continuous furnace using this type of heating, is the temperature of the work controlled by varying the speed of the work or the quantity of the fuel? How does the cost of heating by this method compare with the conventional method?

M. K. Morris: I would like to know if any efforts are being made to construct carbureting equipment to make it possible to use by-product gas, so as the unit will not be fouled by dirt?

A. J. Fisher: I would like to have Mr. Hess discuss the Btu rate per unit of volume burned in premixed gas furnaces.

A. W. C. Smith: Can you apply fuel oils to your burners instead of gas?

F. O. Hess: The first question concerns the ability of the operator to determine the temperature of the work piece in the furnace. We use optical pyrometers on large work, provided the surface is such that optical pyrometers can give accurate measurement. Where fast heating rates are required, results can be accomplished only by means of accurate timing. Present-day temperature control instruments are not suited for measurement at such heating rates. Induction heating is up against the same problem, and we are all looking to the instrument people for further development. On one particular operation, with a speed of about 10 feet per minute, we have recorded temperature variations of better than 200 F within a space of only 6 inches. At the same time, we knew that with the heating equipment involved such variations would be impossible to plan and produce.

This also answers the question about continuous furnaces, where we have two means of controlling temperatures — one, by varying the speed, the other, by varying the heat input. The former, of course, can be accomplished much more rapidly than the latter, which has led us into the continuous application of heat on bar stock. In such cases, we vary the speed of travel through the furnace with electronic instruments. The problem becomes extremely acute when we think of steel strip operation at 500 feet per minute, requiring control by variation in speed.

I failed to point out when we had the radiant panels projected on the screen that control, in that particular case, is effected by moving the panels closer together or farther apart. If the flow line of the tin on the sheet varies, we adjust the spacing of the panels by means of motor operation. The use of radiant heat permits instantaneous reaction, very much faster than can be obtained by throttling the gas input.

Mr. Morris' question concerning the use of dirty gas is an interesting one and is one which arises almost every time we talk to steel people. The usual question is "What can you do about using dirty gas?" and our usual answer is "Nothing." It is impossible to use dirty fuel for precision work. We are trying to provide for the use of the available large volumes of dirty gas in steel mills and believe that it is possible to design gas straining devices which will make practical the utilization of the dirty gases by cleaning them at the operating end of the line. We can't get proper results with crude burners, some things are hard enough to do with refined burners, and we can't get proper results with crude fuel.

Mr. Fisher asked about Btu releases. We have gone as high as 40 million Btu with the slot type burner and can liberate as high as 3 million Btu per cubic foot of combustion space in the radiant type burner. Higher Btu releases are a matter, as far as we are concerned, of further ceramic development which we are studying at the present time. These ratings, of course, are considerably in excess of standard Btu release per cubic foot.

Next, I believe, there was a question concerning the cost of fuel as compared with that in the standard furnaces. My answer will be in the form of a specific example on one of the tube heating jobs, continuously heating tubing at a rate of from 20 to 40 feet per minute, with a tube size of 1½ to 2 inches and a quarter inch wall. The total efficiency on that job is recorded at about 25 per cent of the total heat input. The steel is stainless; we are annealing it, raising its temperature to 2150 F. The rest of the heat is thrown away for we are not making an attempt to recapture it by recuperation, and we feel that a 25 per cent overall efficiency is good for a steel mill in such operations. It is highly possible that this efficiency can be raised in the future with the use of recuperation. We do have one very definite advantage in regard to fuel efficiency, however, the equipment becomes so much smaller with this method of firing that the reduced radiation losses through the smaller wall areas almost compensate for the discharge of the gases at high temperatures. No matter how small we make the equipment, however, there always seems to be less space available in the steel mill.

The last question concerns the application of fuel oil to our burners. As far as we are concerned, we prefer to stick to gas; it keeps us busy enough. This same question has come up on several occasions and, although we have given it thought, we have not entered the field of fuel oil firing.

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Silicone Resins RAISE Insulation Temperature Limit

. . . . silicone insulation and its possible effects on motor design because of its resistance to high temperature have intrigued many motor users . . . . this paper describes a number of silicone applications to motors and test results of the operation of such motors . . . .

by R. F. Horrell, DESIGN ENGINEER
MOTOR ENGINEERING DEPARTMENT
WESTINGHOUSE ELECTRIC CORPORATION
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▲ APPLYING silicone resins to insulating materials makes possible a weight reduction of 50 per cent in certain general purpose industrial motors. These resins, when used in combination with inorganic substances such as mica, asbestos, and fiberglas, produce materials which have a higher thermal endurance than the conventional materials in use today as these are restricted by temperature limits set by The American Institute of Electrical Engineers Standards No. 1. These temperatures are based on the thermal endurance of the conventional materials and such endurance becomes the primary basis for establishing general machine ratings. Therefore, any development which greatly improves the thermal endurance of insulation is of real importance to the user of industrial motor equipment. However, there are frequently other design considerations which outweigh thermal endurance so that on some equipment little advantage can be gained. Each application must, therefore, be analyzed carefully by the design engineer.

"What is silicone?" and "In what form is it available?" Silicone is a generic name applied to a considerable group of semi-inorganic compounds which link the organic and inorganic materials. Several of these silicone compounds are resins resembling organic varnish resins in their physical characteristics. The molecule of the silicone resins has an inorganic structure, a silicon-oxygen chain, so that the resins have tremendously greater thermal endurance than the best of the conventional organic resins. Many combinations of molecular structures are possible with these silicone materials, and they may serve numerous purposes. For example, they are used as insulating varnishes, insulating resins, lubricating greases, filling compounds and fluids for various applications.

Silicone varnishes are available in forms similar to those with which the industrial motor user is familiar. Some silicone varnishes are made with organic solvents; others are of the solventless type. They are used to impregnate and dip-coat coils, insulation, and wound equipment by processes similar to those in which organic varnishes are used. Silicone varnishes normally

require higher baking temperatures than do organic materials, usually 225 to 275 Centigrade. For this reason, it is essential that a very minimum of organic material be contained in the insulation at the time of the high temperature bake. Therefore, organic resins must not be used in the manufacture of composite insulation to be used in conjunction with silicone varnishes.

If the design engineer is to attain the maximum utility of the thermal endurance of the silicone resins, both surface and sub-surface insulation must be thermally stable and moisture-proof. A complete line of insulating materials incorporating silicone resins with various inorganic base substances such as mica, glass, and asbestos has been developed, with limited availability. These materials are available in the same forms as the more familiar class B materials and a list of them is shown in Table I.

TABLE I

Available Forms of Silicone Resin Insulation

Item	Size	Use
Silicone varnished glass cloth	Continuous rolls 18 in. wide and 0.004 in. and 0.017 in. thick.	Backing or composite
Silicone-glass-mica wrapper	Sheets 18 in. x 36 in. x 0.008 in. and 0.010 in. thick.	Coil wrapping
Silicone-glass-mica glass material	Sheets 18 in. x 36 in. x 0.023 in.	Slot cell liners
Silicone-glass-mica wrapper	Sheets 18 in. x 36 in. x 0.015 in.	Phase insulation in stators
Silicone varnished glass covered wire	All standard sizes.	Magnet and stator winding
Silicone filling cement		Plastic filling cement, not rigid
Silicone bonded glass-mica tape	All standard widths. Thickness, 0.0055 in. and 0.0075 in.	Ground insulation for coils
Silicone sized glass tape	Widths up to 1 in. Thickness up to 0.015 in.	Protective outer wrapping for coils
Silicone sized asbestos cloth	Sheets 36 in. x 36 in. x 0.035 in.	Cushioning material

Small induction motor stators have been wound with silicone bonded glass-mica slot cells; with silicone varnished glass-covered wire for the coils; and with silicone bonded glass-mica phase insulation. The completed stator was then vacuum impregnated in the high-temperature silicone varnish to furnish the waterproof external coating.

The field coils of small direct current motors have been wound with glass covered silicone treated wire and given a vacuum impregnation and two dips before being placed on the pole pieces. These same materials were used in the armatures, but baking temperatures were lowered to 200 C because the solders now available are likely to flow at 250 C. Still other silicone materials have been used in larger machines where pre-insulated and formed coils are used. For example: silicone bonded glass-mica tape has been used for ground insulation; silicone sized glass tape has been used for the outer protective wrapping; coils have been impregnated with silicone varnish; and the completed armature or field given a final dip and bake in silicone varnish.

The superiority of silicone varnished glass cloth as compared with a Standard Class B varnished cloth after twenty-four hours at 250 C has been demonstrated. The silicone treated cloth retains its original flexibility; whereas the class B material is severely darkened and embrittled in addition to losing its desirable electrical properties after only two hours. The panels in Figure 1 illustrate aging characteristics of silicone and a high grade organic varnish. Samples A and B are unaged panels coated with silicone and an organic varnish respectively. Samples C and D are the same materials after aging two and one-half hours at 250 C. These samples were tested in accordance with the American Society of Testing Materials heat endurance test procedure which specifies bending the panels around a one-eighth inch mandrel through 180 degrees. Sample E is silicone varnish aged at 250 C for 200 hours and subjected to the same test. While not illustrated, some types of the silicone resin have withstood this test after aging more than 1000 hours at 250 C.

Further measurement of the behavior of the silicone films on aging is shown in the curve of Figure 2. The per cent elongation to mandrel failure of 2 mil films has been plotted versus the aging time at 275, 250, 225 and 200 Centigrade. For comparison, a curve is shown for 2 mil films of an organic varnish used in class B equipment aged at 200 Centigrade. From this data it has been found that in the range from 200 C the silicone resins rather closely follow the "ten degree rule"; that is, that the life of the resin doubles for each 10 C drop in temperature. In Table II, data taken from Figure 2 illustrates this rule.

Silicone insulating materials offer somewhat more resistance to moisture than the conventional materials which use organic varnishes. Stripped films were used in the test for determining moisture permeability by clamping them as membranes over the open mouth of Payne permeability cups and measuring the weight loss under a controlled temperature and in a dry atmosphere. Data obtained shows that no more water seeps through the unaged films than through the better waterproofing insulating varnishes or soft vulcanized rubber. After aging for thirty days at 200 C the silicone film has shown a consistent trend toward improvement, whereas organic films cannot be depended upon as they may or may not improve. Tests on complete equipment confirm these findings. On equipment given moisture and thermal cycling tests, the resistance to moisture has improved with time.

Some low viscosity silicone fluids of the lubricant type make excellent water repellents. These fluids prevent water from forming a continuous film on a surface treated therewith. It has even been suggested that paper raincoats could be made; and fishermen regard the fluid as excellent for floating dry flies in fast water.

One very interesting vibration and thermal cycling test was conducted on a group of silicone-insulated and class B insulated coils. Various methods of insulating were incorporated. Coils tested used materials such as mica tape, glass and asbestos wire covering with various types of mica wrapper, and glass and asbestos finishing tape. One of the groups of coils was made up of silicone treated glass covered wire, silicone bonded glass and mica wrapper, and silicone sized tape with silicone treatment applied to the completed coil. These various coils were placed in a twenty-eight inch diameter d-c motor armature with a twenty-eight inch core length for convenience only. The armature remained static and was vibrated by external means. Severe thermal cycling was obtained by supplying 750 amperes, 420 volts, a-c, 72 times per minute. This load was intermittent and was held for three seconds duration. During this test, temperatures in the order of 230 C were observed. The tests covered sixteen hours per day for a period of thirty-six days. Examination of the test coils revealed that while some of the class B insulated coils had not failed, they showed signs of thermal aging and embrittlement of the resins. The silicone coils not only withstood the test satisfactorily, but the insulation was still in excellent condition.

TABLE II
Failure Time in Hours of Silicone Insulation

Aging temperature degrees C	Elongation of test sample—Per cent				Craze failure time
	14.4	7.2	3.6	1.8	
250	36	55	63	80	85
225*	225	290	375	500	590
225**	205	314	360	456	485
200*	1060	1630	....	....	....
200**	1160	1790	....	....	....

*Actual.
**Calculated by 10-degree Rule.

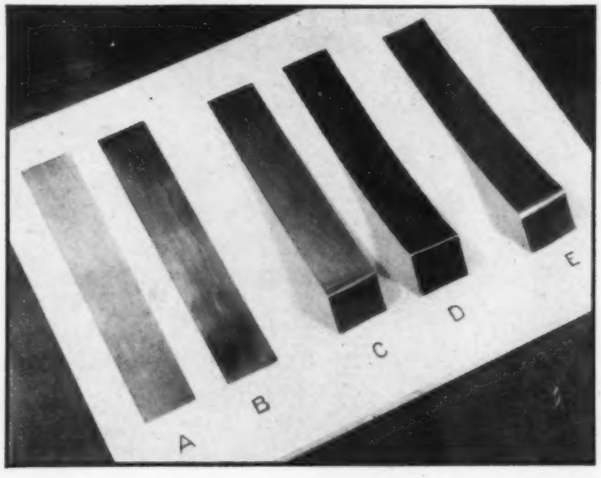
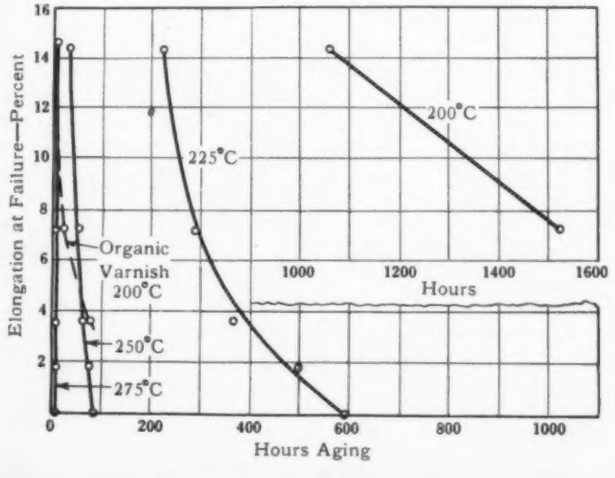


Figure 1 — Test specimens showing aging characteristics of organic and silicone varnishes. Specimen E has a silicone varnish shown after 200 hours at 250 C.

▲

Figure 2 — Test curves of silicone films aged at four temperatures compared with an organic varnish at 200 C. Varnish film is 0.002 in. thick.



In order that the life of the silicone insulation be at least equivalent to that now obtained with class B insulation, it is suggested that the limit for the permissible observable temperature by resistance be set 40 C above the present class B limits. This general rule is offered because certain types of equipment have special temperature limits for class B insulation. It is proposed that the general limit corresponding to A. I. E. E. Standards No. 1 be 175 C for hot spot temperature. This includes a 5 C increase in the allowable difference between the observed value and the hot spot temperature.

There are three important ways in which improved thermal endurance properties may be utilized by design and application engineers in the industrial field. They are:

1. A reduction in size and weight of electrical equipment is possible where the operating temperature can be increased and where no reduction in insulation life can be tolerated.
2. Increased service-life of the insulation can be obtained where it is desirable to maintain conventional size, weight and temperature limits.
3. Operation in ambient temperatures above the permissible limits for conventional types of insulation can be maintained.

All of the applications to which silicone resins and composite insulation have been introduced is beyond the scope of this article. However, here are a few typical examples of their use in various equipment at the present time:

1. Totally-enclosed fan-cooled induction motors.
   (a) Early in 1942 a totally-enclosed fan-cooled induction motor stator was wound for 10 hp using the best available class B insulating materials. This stator was given a vacuum impregnation and two dips in silicone resin varnish. The motor was normally rated 3 hp with class A insulation and 5 hp

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with class B. A series of engineering tests, including overload temperature runs, were made. The overload runs included a thirteen hour test at 300 C total operating temperature, and a peak overload test during which 500 C total temperature on the winding was observed by thermocouple. These tests were followed by an accelerated life test on the insulation during which the motor winding was operated at 210 C rise by resistance (250 C hot-spot temperature) for 3376 hours. The motor was dismantled and examined periodically. The winding was also subjected to a high humidity test. The test was terminated by a bearing failure which resulted in damage to the winding. Figure 3 shows the failure that resulted in molten aluminum running over the winding with little damage to the winding.

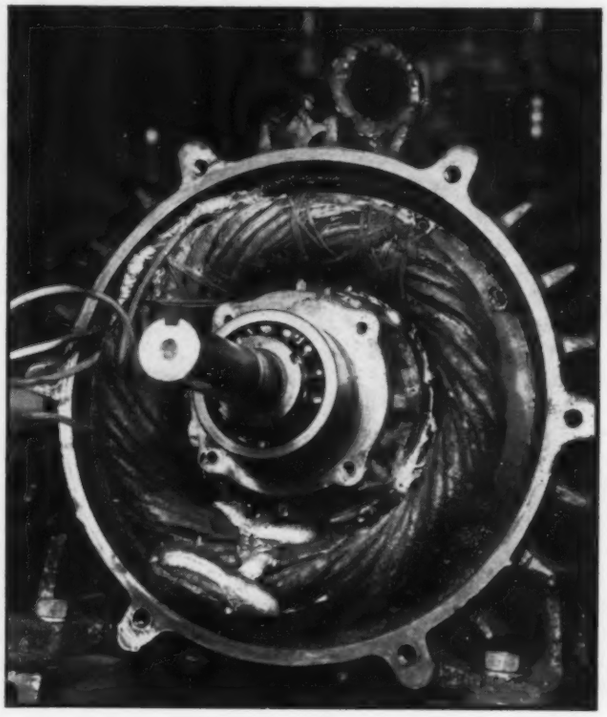
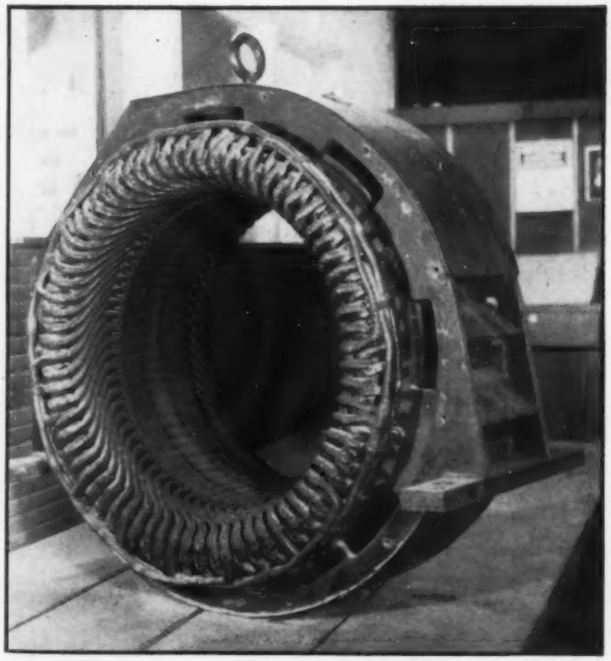


Figure 3 — Totally-enclosed fan-cooled induction motor after test. Test was terminated by a bearing failure. Even molten aluminum did little damage to the insulation.

▲

Figure 4 — After 2966 hours of operation at an estimated hot-spot temperature of 250 C, the high temperature insulation on this 250 kva, 440 volt generator was still in a satisfactory condition.



(b) A second motor was rated 25 hp at 1750 rpm and was built in a 15 hp frame. The motor was insulated as in (a) above. This motor ran for over 3200 hours at 250 C hot spot before a mechanical failure of the bearing stopped the test.

(c) A third motor was built the same as (a) above except that silicone materials were used throughout. This motor is still driving a motor generator set after completing over 4100 hours at 185 C hot-spot temperature. The set is shut down frequently so that in all respects the motor receives actual service.

(d) Another example is a 7½ hp motor which drives a caustic pump in a moist atmosphere. This motor operates twenty-four hours a day and is started once a week. It has been in service for over eleven months as against only a little over five months for a class A insulated motor.

(e) A fifth motor, rated 25 hp, drives an evaporator pump in a wet location. This motor has been in operation for over thirteen months, whereas previous conventionally insulated motors failed in approximately six months.

2. One 250 kva, 440 volt generator was made with silicone insulation throughout the stator. As a preliminary temperature test, the stator was short-circuited at 275 per cent normal current. This load resulted in an observed temperature of 355 C which was held for six hours. Subsequently, the stator was redipped and baked and then subjected to an accelerated thermal aging test. The test consisted of heating the stator on alternate days by loading the unit as a generator. The observed rise by resistance was 210 C or 250 C hot spot. At the end of 2966 hours the test was terminated even though the insulation was still in satisfactory condition, as can be seen in Figure 4.
3. A few mining locomotive motors, street railway motors, and trolley coach motors have been made with silicone materials and are now being tested in the field. Some have already given service far beyond that obtained with conventional materials.
4. Magnet coils for relays and contactors, and several hundred dry type transformers have been insulated with silicone materials and placed in service, and a comparative test is shown in Figure 5.

The foregoing applications are typical of the ways in which the high thermal endurance properties of silicone resins and materials can be applied to industrial equipment. Table III suggests others. It will be noted that some applications overlap, also, that some applications must be carefully studied to insure proper results. For instance, on machine tool motors care

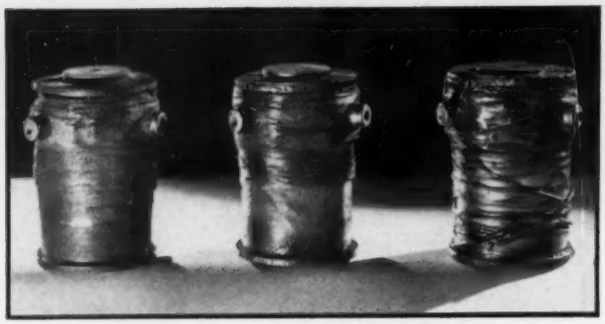


Figure 5 — Comparison of silicone varnish and high grade organic varnish on magnet coils under following conditions: left to right, class A insulation aged 200 hours; class B insulation aged 2750 hours; high temperature silicone insulation aged 5000 hours. All coils tested at 235 C as observed by resistance.

must be exercised to insure that the higher temperatures involved will not affect the accuracy of machining. Another precaution to be taken is one of keeping the bearing temperatures at safe operating temperatures. The safe temperature for grease lubricated bearings is 110 C total temperature if the proper lubricant is used. It may be necessary to provide cooling for the bearings on some machines applied in a high ambient.

It must not be assumed that silicone insulation is a cure-all for motor ills. While an excellent insulating material, it must be applied with extreme care if maximum utilization of its properties is to be realized. As more and more equipment becomes available for handling the manufacturing processes, then, and only then, can there be extensive use of silicone motors.

To completely evaluate the possible advantages to be realized by using the increased operating temperature silicone offers, certain characteristics must be considered. The following study is based on increasing temperature only, the speeds and insulation allowances being conventional. It should be remembered that other problems are introduced, particularly mechanical problems as previously mentioned. Obviously, these problems can be solved only by experience on specific applications. Other considerations relate to performance, efficiency and power factor. In other words, it should be recognized that the major advantages derived from silicone insulation are accomplished only through a balanced design.

Small industrial motors — Most designs in commercial production are class A, 40 C rise machines. Some weight reduction would be possible on certain designs in going to 50 C rise without change in insulation. Further weight reductions would be possible on some of these by using conventional class B insulation. On some motors, such as the open and splash-proof types, the torques, efficiency, and power factor requirements limit the advantages to be gained by use of the high-temperature insulation. On some totally enclosed fan-cooled motors the same factors may well apply. However, there may be more possibilities in redesign for weight reduction because the operating temperature, frequently the limit in design, has been increased. An example of such redsign is shown in Figure 6.

Large synchronous and induction motors — The larger machines and higher speed machines could in some

TABLE III

Suggested Applications For Silicone Insulated Motors

Reduced weight per horsepower by operating at higher temperature with no sacrifice in life	Increased life of insulation while maintaining conventional size, weight, and temperature rise	Operation in high ambient temperatures
Rapid reversing motors	Loaders, drills, shuttle cars, coal cutter motors, etc., in mining applications.	Furnace motors
Fan-cooled motors		Roll table motors
Variable voltage drives where ventilating is reduced at low speeds with normal current in windings.	Motors for creamery applications where humidity is high.	Ventilating fans
Machine tool motors where space is limited.	Motors handling fluctuating loads with high peaks.	Circulating fans handling hot gases
Submarine propulsion motors	Motors operating in caustic and acid fumes.	Dry kiln motors
Marine motors where saving in weight and space are important.	Pickling, cleaning and plating lines.	Copper mining application such as scraper hoists.
Some hoist applications.	Motors used in tropical locations with high humidity.	Cooling tower motors (high humidity and ambient).
Crane motors.		Open hearth department.
Wood working where motors are shell type or built-in.		Bessemer converters, forced draft blowers in marine boiler rooms.
Short-time rated motors with extremely limited weight and space conditions.		Boiler room auxiliaries on shipboard, such as oil burner motors, oil pump motors, etc.

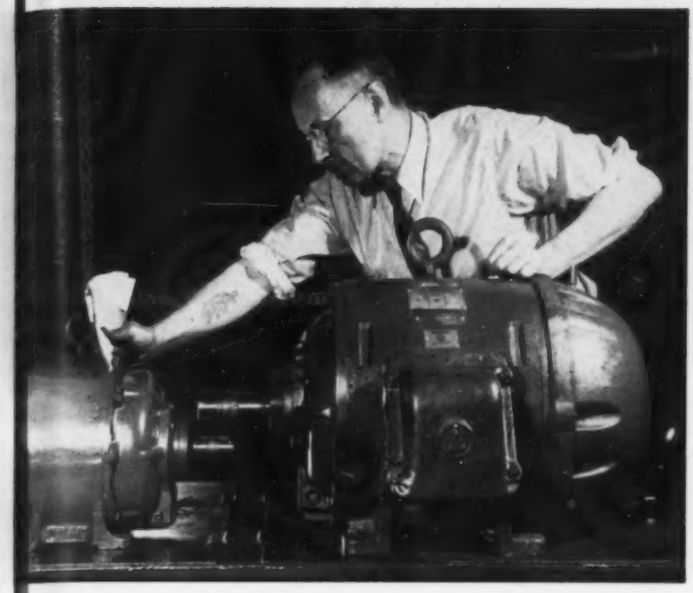


Figure 6 — Despite the difference in size, these two motors each produce 10 hp at 1750 rpm. The smaller has high temperature silicone insulation and weighs 210 pounds, the larger has class A insulation and weighs 410 pounds.

cases be reduced in weight by utilizing fully the present class B temperature limits. In addition, there are some of those larger or higher speed designs which could be made still smaller, if an increase of 40 C were possible above present class B limits. In most cases, the maximum possible gain in size and weight reduction through increase in permissible temperature will require some sacrifice in efficiency, and power factor on induction machines.

Large direct-current machines — The effect of temperature on size and rating of this class of equipment depends upon the design characteristics, particularly on the ratio of copper loss to iron loss. Their design is standardized through establishment of lines of frame sizes to fit widely varying conditions. This naturally results in some machines being larger and heavier than those specifically made to suit a particular application.

As fibrous glass was introduced to various industries, new hopes were held for higher operating temperatures, but suitable treating materials were not available. Now, with silicone resins indicating that the desired results can be achieved, both in the laboratory and in the field, extensive use of high temperature silicone insulation can be expected. Many types of electrical machines are larger and heavier than need be if high-temperature silicone insulation is used. In some instances, it may be desirable to supply renewal parts treated with silicone for existing equipment which has a short life or requires increased power. Since silicone processes and materials are still relatively new and require additional development the cost of the silicone insulated machine is necessarily higher than the more conventional types. In any event, the new silicone materials must not be considered as the cure-all for all insulation problems, but must be applied with caution and vision on specific applications where their use can be justified.

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Iron AND Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

MODERN ALL-WELD STEEL RAIL CAR ADDS TO GROWING DEVELOPMENT LIST

▲ A modern all-welded steel hopper car was added to a growing list of developments of postwar rail equipment by the Railroad Research Bureau of United States Steel Corporation subsidiaries. When empty the new car weighs only 33,500 pounds, 6,540 pounds below that of the car built to the standard carbon steel specifications of the Association of American Railroads.

This car was built of U.S.S. "Cor-ten" to order for Carnegie-Illinois Steel Corporation, a United States Steel subsidiary. The high strength and superior atmospheric corrosion resistance of this type of steel, say the car's designers, permit reduction of the thickness of sections, and will assure longer service life. The welded joints greatly simplify construction, provide seals against moisture, and eliminate laps.

In general, the car does not differ radically from the lines of conventional A.A.R. standard design, but all protruding structural members and seam ledges have been eliminated from the interior by means of outside stake side construction. Side framing provides additional horizontal stiffness to compensate for the omission of inside diagonal center braces. This smooth interior surface permits free flow of burden during unloading and helps to avoid damage to the car by loading and unloading devices. Ledges and pockets where moisture may collect are also eliminated, thus reducing the possibility of corrosive attack.

The saving of weight permitted by the use of high-strength "Cor-ten" has been translated into increased cubic capacity, which allows more revenue freight each time the car is loaded, say its builders. Because of its lighter weight, the all-welded car is equipped with empty load brakes.

To obtain maximum unloading area in the door openings, and also to reduce weight, a welded tubular center sill has been installed, which facilitates the use of a one-door opening across the car. The hopper sheet of the car bottom, which is formed by two simple bends, extends in one piece from one side of the car to the other.

The sides are made up of two longitudinal sheets of "Cor-ten", a heavier sheet in the lower portion, which receives more wear and abuse. This heavier sheet serves as a framing member for the attachment of cross members and floor sheets. The upper sheet, of lighter gage, also extends from end to end of the car. Both sheets are welded to a structural frame consisting of vertical posts and top chord and an angle section side sill or bottom chord, the latter sloped, forming a water-shedding shelf.

Since 1934, when U.S.S. "Cor-ten" was introduced, car builders and railroads have used this versatile high-strength steel in more than 65,000 freight cars, with an average saving in

TWO EXPERTS INSPECT GIANT CRANE

BUD SCOTT PHOTO

Bob Harry, vice-president of Alliance Machine Company, is asking Frank W. Cramer, electrical engineer of the Carnegie-Illinois Steel Corporation, if he had ever seen a crane as large as this one. The occasion was a recent visit to the Alliance Machine Company plant at Alliance, Ohio where the company was host to a small group of steel company officials who came out to see what is in some respects the largest crane in the world. The crane which was built for the Navy consists actually of two cranes which are designed so that they can work together to lift a single load of 450 gross tons through a loading beam. The girder spans are 142 ft; the girders are of the truss type with a lattice out-rigger girder, and so deep that they could not be assembled entirely in the shop because of overhead crane clearances. These cranes have many unique features which have never before been built into other cranes.

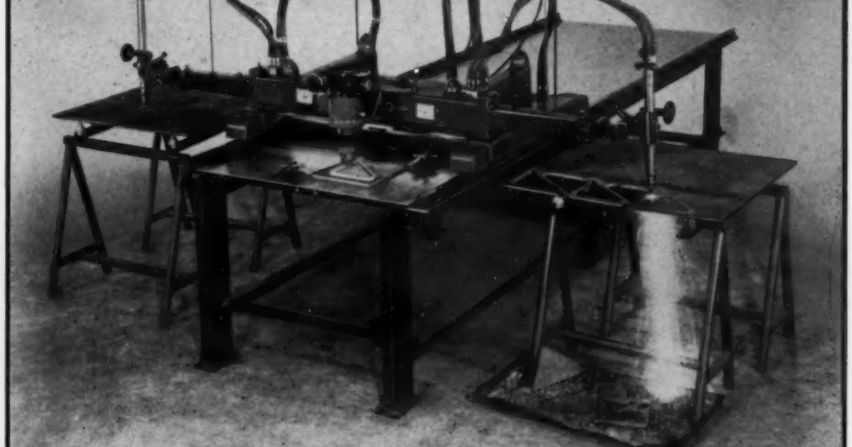
dead weight of more than 2½ tons per car. The operating records of these cars, say the United States Steel designers, were thoroughly studied in preparation for the building of the new all-welded lightweight hopper car.

FIRST POSTWAR MODEL OF SHAPE-CUTTING UNIT

▲ The first postwar model of an "Oxweld" oxy-acetylene shape-cutting machine, the CM-15-36, has been announced by the Linde Air Products Company, a unit of Union Carbide and Carbon Corporation, New York, New York.

The new machine has been designed to do precision cutting on work of intermediate size, which formerly could be done only with a large machine. For the first time on any shape-cutting machine of this type, attachment is available for this machine which makes it possible to mount the blowpipes on both sides of the tracing table. This feature makes the machine particularly adaptable to high production setups by permitting the cutting of identical shapes simultaneously from plates on both sides of the tracing table. The attachment can also be used to great advantage in eliminating "down time," since plates can be put into position on one side of the machine while cutting is being done on the other.

All types of shape cutting performed with larger machines are possible with this machine within its 36 inch transverse working range. The longitudinal working range with the standard table is 100 inches and this range can be extended indefinitely by adding frame and table top sections.



This new machine has been designed to do precision cutting on work of intermediate size which formerly could only be done with a large machine.

NEWLY DESIGNED PRESS HAS UNUSUAL FEATURES

▲ A newly designed Lake Erie hydraulic press for bending and forming steel parts that has a number of rather unusual features is now being manufactured. The press is a 200-ton "C" frame type with a 42 in. right to left and 24 in. front to back die space. It has a 30 in. daylight opening and 16 in. stroke. The five things that make this press outstanding are its high speed, great strength, compact size, clean design and cushion in bed.

The press has a closing speed of 350 in. per min and a return speed of 345 in. per min. It has a welded steel housing with extra-heavy "C" frame construction for minimum deflection under load. The upper or moving platen is rigidly guided, for added strength and accuracy. There is a 35-ton cushion in the bed, The press is operated by hand lever readily accessible to the operator, and sensitive control of operating speed is obtained by direct stroking of the pump. The first of these presses is now being installed in the McCormick Works of the International Harvester Company in Chicago., Illinois.

PORTABLE BRAZER FOR MAKING LAP JOINTS

▲ For making lap joints in copper strap, attaching terminals to cable, brazing coil ends and general copper smithing work, a new portable 5 kva brazer weighing only 30 pounds is announced by the Westinghouse Electric Corporation, East Pittsburgh, Pennsylvania.

The new brazer, which requires connection to a 220-volt source, consists of a transformer, voltage selectors, controls, and carbon-tipped tongs. Alternating current from an adjustable voltage transformer passes through the tongs and parts to be brazed, raising the temperature to a point at which the brazing alloy melts. The brazing alloy may be applied in the form of a rod or in ribbon form. Three outlets are provided on the control panel for 8, 6 or 4 volts. Voltages are easily and quickly adjusted by inserting bayonet plugs attached to the brazing leads into plainly marked receptacles. A foot switch with pilot cable serves as the primary control switch.

For use with air-cooled tongs, the new brazer is supplied with a handle for carrying. The 30-pound unit is cooled by natural air circulation. Air enters bottom of the case and is expelled through louvered openings in the top.

HIGH-ALLOY CAST IRON ROLLS IN THE POSTWAR EXPANSION PERIOD

▲Continued use of high-alloy cast iron rolls in mills engaged in war production has brought out many virtues of the new rolls that will be of benefit in the expanding postwar period. One of them is their adaptability in cold rolling. Although availability and a lower initial cost probably have been the immediate reasons for the recent trend toward these rolls which were pioneered by the Mackintosh-Hemphill Company, Pittsburgh, Pennsylvania, ultimate economy in both time and money insure their more universal use. Some mills already have been completely equipped with these rolls.

An important asset of the new "Nironite D" rolls to mills turning out products for the postwar world is the remarkably hard, wear-resisting working faces which have a scleroscope hardness of 85 to 90. Therefore they have a resistance to surface indentation or marking equal to that of 90 to 100 scleroscope steel. This enables them to attain and retain an unusually high polish which imparts an unmarked, mirror-like surface to the product. Polishing of these rolls also is required less frequently. If dull-finished stock for subsequent coating is desired, the rolls are said to take an excellent sandblasted or etched surface which they retain for a long time.

Not only has the new roll proved to be remarkably resistant to spalling, but such spalling as does occur is very shallow and easily removed by grinding. After redressing, it is not necessary to return the roll to the producer to have the surface hardened again. The hardness of this roll penetrates very deep, permitting redressing many times without the need for rehardening. Actually, it is said the roll can be ground down to the minimum diameter that can be used in the mill and still retain its original hardness. This results in the saving of both the time and expense necessary to return the roll to the producer for rehardening.

The journals and inner central portion of the body are of soft, strong, grey iron, making the rolls capable of withstanding the pressure of the mills and the torque of the mill drive with little possibility of exploding. This is true not only because of the depth of the hardness, but because of its naturalness, this hardness having been obtained in the process of casting by the chilling action of the metal mold upon the body of the roll. "Nironite D" rolls are said to be very stable and to stand considerable mechancial and thermal abuse without damage. No additional mill precautions over those ordinarily required for standard rolls of equivalent hardness are said to be needed with the new rolls.

Another advantage of the new rolls is that no axial coolant is required as they maintain their shape under the conditions of heat as normally experienced in cold rolling. These rolls already have been installed as work rolls on 4-high tandem, single stand, reversing and temper mills.

A Practical Means TO CLOSER QUALITY CONTROL

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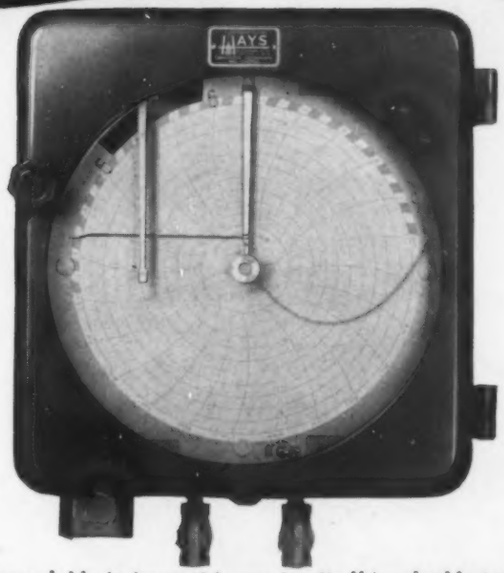

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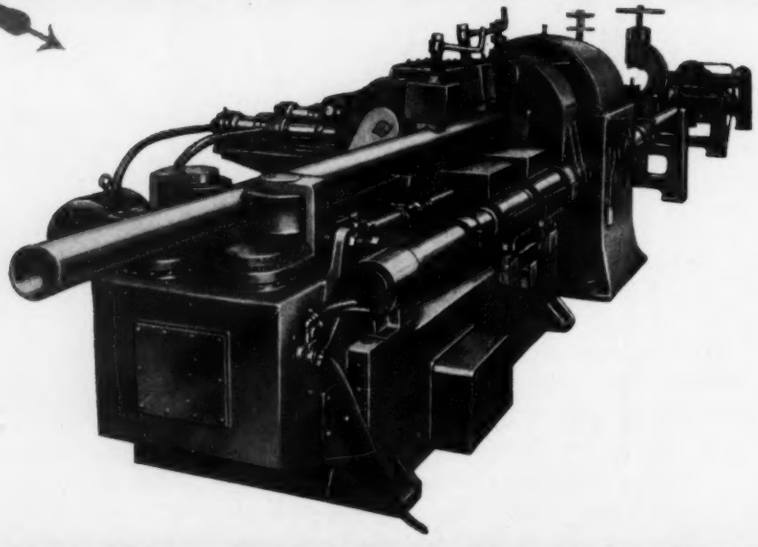

MANUFACTURING ENGINEERS OF COMPLETE TRANSMISSION EQUIPMENT AND SPECIALIZED MACHINERY

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THE MEDART COMPANY — 3100 DE KALB ST., ST. LOUIS, MO.

BUILD DIESEL ENGINE FOR STATIONARY USE

▲ A "V" type engine, new and radically different from other Cooper-Bessemer diesels and designed to pack more horsepower into less space and with less weight, has been announced by the Cooper-Bessemer Corporation of Mount Vernon, Ohio, and Grove City, Pennsylvania. The new engine, the "FV," is built to furnish power for various stationary and industrial applications. It is a four-cycle engine with a 9-inch bore and a 10½-inch stroke and is being built in 12 and 16-cylinder models.

Among its distinctive details of design are a four-valve head, a one-piece cylinder and head assembly, and a geared accessory drive which is enclosed in the main frame. The main frame, which carries an underhung crankshaft, has bearings located in the cross-ribs. These are the precision-ground, interchangeable type. There are two banks of cylinders bolted to the top of the frame forming a "V" with an included angle of 45 degrees, or 22½ degrees from the vertical center line on each side. Each cross-rib is bored in two places to hold bearings for the two camshafts. The top of the frame is drilled over each cam to take the push rod guides and assembly. Removable inspection covers on each side of the frame provides ready access to the crankshaft and camshaft. A crankcase oil pan is bolted to the under side of the main frame.

The crankshaft, machined to close dimensions and highly polished at the bearing areas, will be of forged steel or cast Meehanite, depending upon the application for which it is built, the connecting rods are of articulated design with one rod serving as the master. Piston and connecting rod pins are of the saddle-end design which offer a maximum bearing surface. The pistons are oil-cooled, affording even distribution of heat and improved operating characteristics.

The entire cylinder and head assembly is cast in one piece, a striking departure from the usual design and it includes a jacketed cylinder, a cylinder head containing main valves, air-starting valves, a fuel-injection nozzle and a support which carries rocker arm parts and fuel pump.

FRIENDS AND CO-WORKERS HONOR WRAY DUDLEY AS HE RETIRES FROM NATIONAL TUBE COMPANY

The entire maintenance department of National Tube Company at McKeesport and a host of his other steel mill friends turned out to honor Wray Dudley on April 6, as he reached the company's retirement age. Mr. Dudley spent many years with the U. S. Steel Corporation the last ten years of which were spent at National Tube. He is pictured above (third from left) with J. J. Bangert, V. J. Nolan and J. G. McNeely. Mr. Wray Dudley has been a member of the Association of Iron and Steel Engineers for more than 25 years and was assistant superintendent maintenance department at National Tube at the time of his retirement.

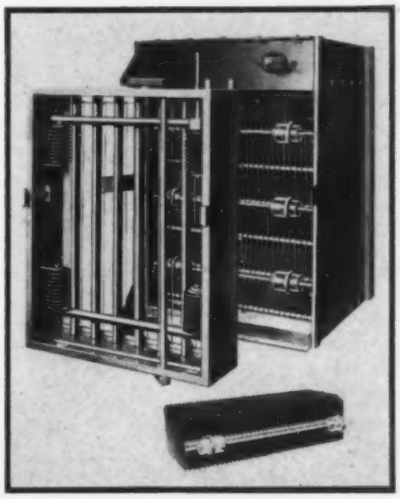
LATEST UNIT TYPE AIR FILTER IN PRODUCTION

▲ The "Electro-Cell," a unit type electronic air filter with removable collector plate assemblies, is one of the latest type now being manufactured by the American Air Filter Company, Inc., Louisville, Kentucky.

The positive and negative collector plates are assembled on cross rods to form horizontal groups which are easy to handle and may be readily removed from the filter casing. This makes possible a number of innovations in construction which simplify installation, improve performance, and assure better maintenance.

Sliding into the filter casing in much the same manner as a desk drawer, plate assemblies can be removed for cleaning and reoiling at convenient water and sewer connections. By keeping a spare set of plates sufficient for one section for use as a replacement, the length of time the filter is out of service is reduced to a minimum and the dirty collector plate assemblies can be cleaned at a time that is most convenient for maintenance personnel. An automatic washing device has been developed permitting collector plate assemblies to be washed in place for installations where manual washing is not feasible.

Collector plates on this air filter can be removed for cleaning and reoiling.



Standard sections of the electronic air filter are two and three ft in width with a capacity of 1,000 cfm per unit and range from this minimum to as many sections as are needed for the particular installation. The construction of the filter is such that it eliminates the duplication of top and bottom sections of box-like units when assembled one upon another. This is accomplished by the manufacture of the filter in a variation of heights from a minimum of 27 in. to a maximum standard height of 15 ft by 9 in. increments.

In the large sizes of the filter (6 ft or higher), the ionizers are mounted on a bar hinge which swings clear of duct work or adjacent sections giving full access to collector plates. Ex-

VALVE SOLVES PROBLEM OF LIQUID FUEL FLOW

▲ The new differential oil flow control valve, designed by Bloom Engineering Company, Pittsburgh, Pennsylvania, is said to solve the problem of obtaining constant liquid fuel flow to regenerative furnaces, regardless of variations in pressure before or after the valve.

Instantaneous in action, the new valve holds liquid flow constant — completely eliminating flow changes due to pressure variations caused by reciprocating pumps on the fuel system, reversal of adjacent furnaces on the same fuel line, steam pressure changes to the oil burners, varying resistance of oil burners, dirty burners, changes in burner settings, and other causes of pressure fluctuation normally experienced in most fuel systems.

The open hearth furnace, most important of liquid fuel consumers, is also the consumer whose fuel control problem is most difficult. For this reason, the open hearth problem was selected for solution. The differential oil flow control valve has been developed under actual steel mill operating conditions. However, the application of the valve in many other liquid fuel control problems has been made and the valve demonstrates that any oil burner operation can be improved by its use. Each valve is precision tested and calibrated at the factory. The position of the valve handle is a direct measurement of oil flow. Metered flow can be provided for remote indication or for application to combustion control apparatus.

DIAL INDICATORS POSSESS WIDE VARIETY OF PRACTICAL USE

▲ Dial indicators and dial indicator gages made by Federal Products Corporation, Providence, R. I., have a wide variety of practical uses in the fabrication of iron and steel products. The practical applications of Federal instruments which follow give some idea of the diversity of uses to which dial indicators and indicator gages may be put in iron and steel fabrication for controlling dimensional and physical conditions which can be converted to linear dimensions. For instance, dial indicators are used on "depth of penetration" gages (illustrated in Figure 1) to accurately measure the hardness of metals. A sample of the metal to be tested for hardness is placed on the lower compression platen. Pressure is then applied to the penetrator. The depth of penetration by the penetrator into the metal specimen is accurately recorded on the indicator dial. Depth of penetration gages, of which dial indicators are an essential and integral part, can be used for production inspection where speed, combined with accuracy is demanded, as well as for laboratory use, where the most exacting requirements must be met in testing metals.

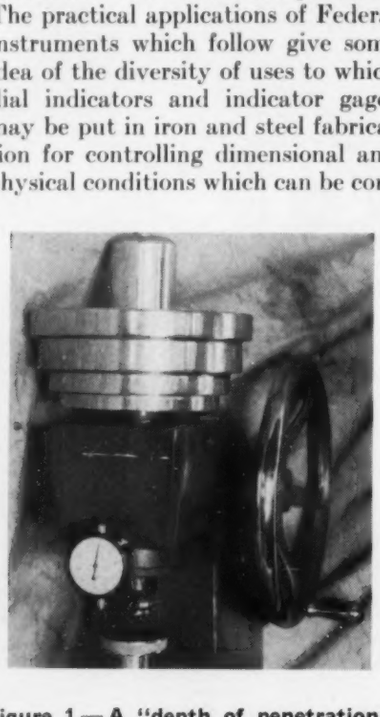


Figure 1 — A "depth of penetration" gage is used to accurately measure the hardness of metals.

Dial indicators are used to accurately measure the size (i.e. outside diameter), as well as the concentricity and straightness of ground and polished steel shafting. The uniform dimensional accuracy of shafting is very important if the shafting is to be free from vibration, and have maximum operating life. Dial indicators and indicator gages insure this essential dimensional accuracy.

The indicator shown in Figure 2 is an inspection device used for the continuous control of the thickness of strip stock. Formerly a hand mike was used, but with this it was not possible to inspect every inch of the stock, and defective sections resulted because, here and there throughout its length, the stock ran either over or under the specified dimensions. Now by the use of this dial indicator equipped device, the strip is inspected 100 per cent throughout its length. Inspection is three times as fast as it used to be when hand miked. The strip stock is fed between motor operated rolls. The inspector cuts out portions of the stock that are shown to be dimensionally inaccurate by the dial indicator readings.

Figure 2 — This dial indicator is an inspection device used for the continuous control of the thickness of strip stock.

Dial indicators are also used to gage the trueness of heavy shafts on an hydraulic straightening press. The need for accurate dimensional control on such work is obvious. The dial indicator is mounted on a test set which is placed at any desired point on the bed of the press.

These practical applications of dial indicators give some idea of their ever widening use for the precise control of dimensional accuracy in the fabrication of iron and steel products. To meet the most recent demands for precision measuring technique, the company now markets an electronically operated gage of great versatility and accuracy, as well as a "Metricator" air gaging system which has many unique features.

INDUCTION HEATING UNIT HAS MANY APPLICATIONS

▲ Use of induction heating with somewhat the same flexibility as the old-fashioned soldering iron or oxy-acetylene torch is now possible by means of the flexible lead and coil set-up developed recently by the Induction Heating Corporation, New York, New York. The heating coil is mounted on a convenient grip-type handle and is connected to a standard "Thermonic" output transformer by specially designed flexible leads. This innovation greatly extends the scope of applications of high-frequency induction heating since it is no longer necessary to bring the work to the heating coil.

By means of flexible leads, the coil can now be brought to the work so that many bulky assemblies, which previously did not lend themselves to induction heating, can thus gain the advantages inherent to the use of induction heating equipment. Suitable for both heat treating and brazing, this new coil is being used extensively in annealing such sections as the ends of large shafts and in brazing large, tubular steel assemblies. The heating coils used can be either single or multi-turn coils, although the single-turn inductors limit to some extent the amount of power which may be transferred into the work. Present indications point to the ultimate use of a split, single-turn coil of

the clip-on type, which can be used for brazing continuous, closed tubular structures and piping assemblies, thus greatly speeding up the soldering and brazing of such parts as refrigerator assemblies, tubular metal furniture, bicycles, and similar items.

By use of these output transformers, the terminal voltage of the coil is reduced to such a value as to minimize the danger of arc-over to the work, and any hazard to the operator. This does away with the necessity of keeping the work precisely located within the coil, and enables unskilled operators to solder or braze joints with little instructions.

CRUCIBLE STEEL SPENDS $2,500,000 ON NEW MILL

▲ The Crucible Steel Company of America has placed an order with United Engineering and Foundry Company, Pittsburgh, for a six-stand 24-inch billet and bar mill for Crucible Steel's plant at Midland, Pennsylvania.

The cost of this installation will amount to more than $2,500,000, it was announced.

This mill, with its auxiliary equipment, will roll billets, bars, tube rounds and large rounds up to 8-inch diameter in carbon and alloy steels.

The arrangement of the mill incorporates new features not heretofore embodied in mills of this type and will supplement Crucible's existing facilities to permit more efficient production of this company's range of finished and semi-finished products.

NEW WATER COOLED DOOR FOR HEATING FURNACES

▲ A new water cooled door for open hearth and heating furnaces (J. F. Sticker type) has been announced by the William M. Bailey Company, Pittsburgh, Pennsylvania.

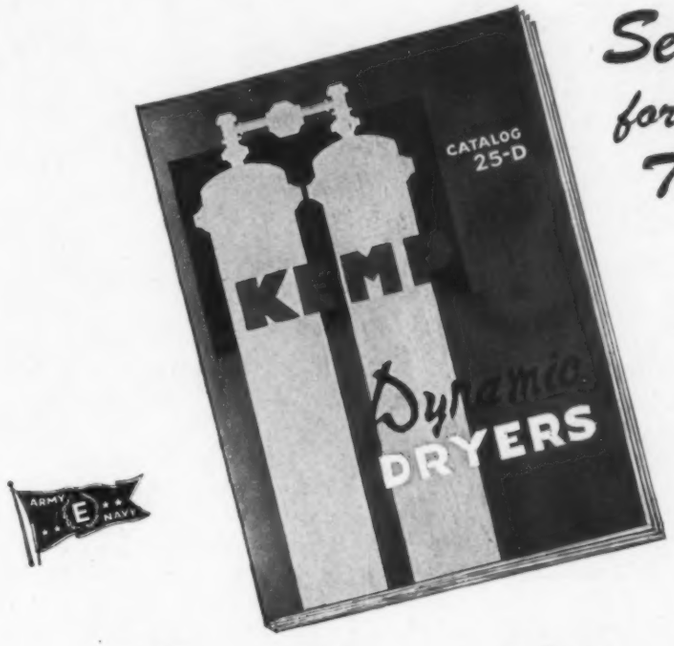
In the new Bailey door, manufactured for all open hearth and furnace sizes, water cooled ribs divide the plastic refractory into easily cooled sections, which not only add strength to the door but also eliminate warpage, insuring a longer life for both the door and the lining.

Its effectiveness has been proven in a large, eleven-furnace open hearth in West Virginia, where the life of the refractory linings ranged from 150 to 200 heats.

RELIANCE BREAKS GROUND FOR $1,500,000 PLANT

▲ The Reliance Electric and Engineering Company, 1088 Ivanhoe Road, Cleveland, Ohio, will break ground shortly for a new plant in Ashtabula, Ohio. One story in height, the new plant will contain 120,000 square feet of manufacturing area and employ approximately 500 people working on two shifts. The building itself, to be of the most modern construction, will cost $750,000 and with machinery and equipment will represent a total investment of close to $1,500,000.

Work on the new project will be started as quickly as possible and is expected to take the better part of a year. When completed, the new plant will be used for the production of 1 to 15 hp electric motors and adjustable speed drives, the latter a pre-war development which has found increasingly wide application in all major industries.



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TEN TON ELECTRIC TRUCKS NOW HERE

▲ According to the Elwell-Parker Electric Company, capacities of power industrial trucks in general use have increased substantially after each world war due mainly to intensified experience with them. They were in early development at the outset of the first conflict; the best then could lift and carry 2 net tons. As that war progressed 3-ton trucks were built. After it was over many more trucks were required, with capacity for transporting loads weighing 5 tons.

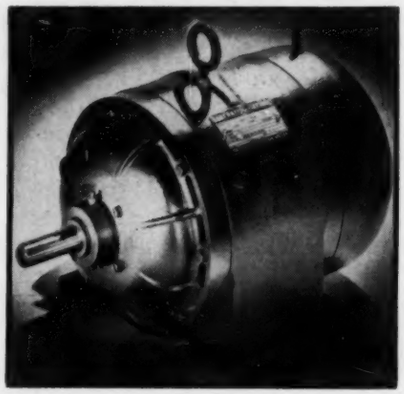
Economies apparent in handling larger tonnages at one time, the secret of fast, economical movement of materials, led to progressive increase in power. Now after World War II, trucks of 10 tons capacity are available for general use.

The new 10-ton trucks are driven by means of storage batteries and electric motors. Their most notable features aside from compactness and power, are simplicity, instant responsiveness, ease in maneuvering; smooth, quiet operation, safety and economy.

The body of the truck is low and the operator has complete visibility of platform, load and surroundings. Overall length is 147 in., width 45 in. It is steered by means of all six of its wheels. Four of these wheels, under the platform, insures stability of the load. It can turn in aisles 71 in. wide. Speed may be accelerated rapidly to six mi per hr, while the truck can come to a "dead" stop within a few feet. Electric drive and controls provide an unusual degree of flexibility.

TOTALLY-ENCLOSED MOTORS DEFEAT CORROSIVE AIR

▲ A new totally enclosed, fan-cooled motor especially designed for use in extremely dusty, dirty, and corrosive atmospheres has been added to the line "Tri-Clad" induction motors, manufactured by General Electric Company, Schenectady, New York. The new motor is available in standard, explosion-proof, and dust-explosion-proof types from 1 to 1,000 hp and can be used where iron dust and metal filings are in the air and in hazardous locations. Short in length and compact in construction, the motor can be installed in a small space, making it suitable for machine tool applications where the motor must be part of the driven machine.



This motor features a double-shell, cast-iron frame, and cast-iron end shields and conduit box for protection from external blows, dripping water, dusts, vapors, and corrosive liquids. Sealed end shields and inside joints, and a one-piece, double-shell stator protect windings, punchings and rotating parts from moisture or corrosive elements. Long, close-running shaft fits, supplemented by a rotating seal, keep dirt from entering the motor along the shaft. Punchings and windings within the inner shell of the motor are cooled by a non-sparking external fan which is protected by a cast-iron housing with a screened air-intake opening.

PENNSYLVANIA STEEL FIRM PLANS NEW IMPROVEMENTS

▲ Several improvements are planned for Central Iron and Steel Company, Harrisburg, Pennsylvania. This company recently came under the control of Barium Steel Corporation, Canton, Ohio. Plans have not as yet been completed, but it is understood that the operations will continue to be confined to plate production and fabrication.

Although the newly affiliated companies will consume a certain extent of Central Iron and Steel Company's production, the company will continue to have sufficient capacity available for its regular customers. Central has an annual rated capacity of 336,000 tons of ingots and over 280,000 tons of finished plate. The plant occupying 80 acres also has a fabricating division.

Central Iron and Steel Company was organized 19 April 1897 by the consolidation of Central Iron Works, which had been formed in 1853, and the Paxton Rolling Mills which had been established in 1869. Products now manufactured are ingots and billets; sheared and universal plates; checkered floor plates; hot rolled sheets and skelp; flanged and dished heads; and steel stampings.

LIGHTWEIGHT INSTRUMENT FOR SORTING OF METALS

▲ A new instrument, the "Metalsorter" type B, quickly identifies and sorts pure metals, steels and nonferrous alloys. It is portable, very simple to operate, of rugged construction, requires no special electrical power supply and makes non-destructive tests on finished products.

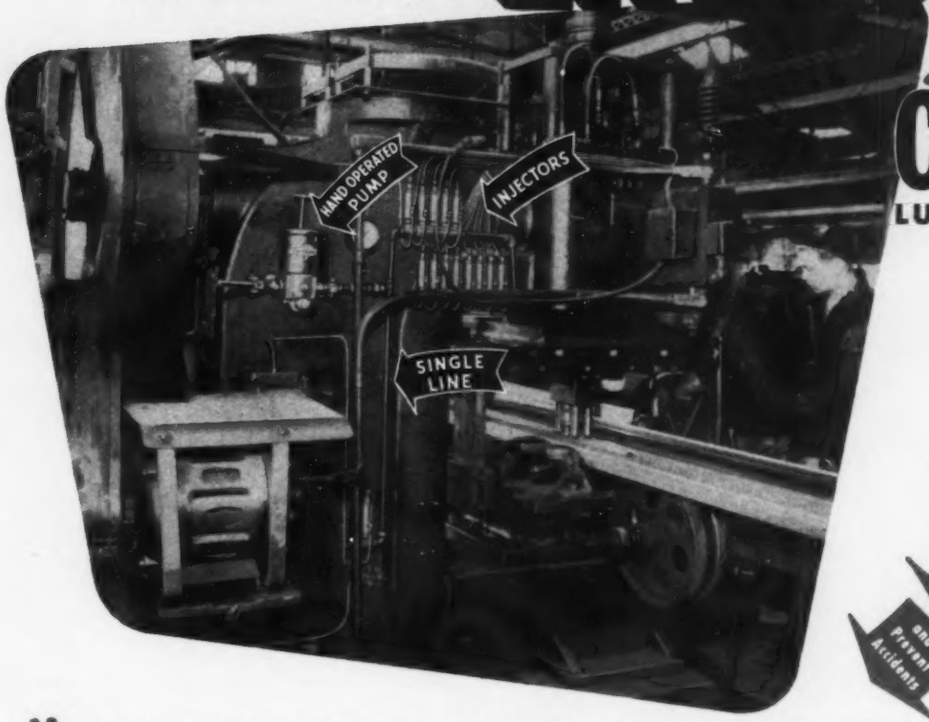
This instrument employs the triboelectric effect. A metallic specimen of standard, known or acceptable character is rubbed against the surface of an unknown or doubtful piece. If a chemical or metallurgical dissimilarity of the two pieces exists, a minute electrical current is generated and is registered by an indicator on a calibrated scale. When there is no dissimilarity, no electrical current is indicated.

The control unit contains a thyratron operated timing circuit, and electronic bias supply and a measuring circuit. A reciprocating tool is connected to the control unit by means of a multiple conductor cable and plug. The tool is provided with a specimen holding chuck and a flexible lead for connection to the metal to be tested.

Various fixtures, tools and connector leads are standard accessory equipment to enable the instrument to use almost any shape of metallic part for a reference standard. Manufacturer is Control Equipment Company, 547 Brushton Avenue, Pittsburgh 21, Pennsylvania.

"Down Time" is *Lost Time!..*

Install LINCOLN *Single line* CENTRO-MATIC LUBRICATING SYSTEMS *and save*



Machine "down time" results in increased production costs—Today's accelerated production has brought out the inadequacies of older, time consuming methods of lubrication—has proved the importance of Centro-Matic centralized lubricating systems for reducing "down time"—saving power—preventing accidents.

Lincoln Centro-Matic Systems help keep machines on the job — and have shown their dependability in many war-time operations of importance—These systems have inherent features of design that are the answer to many troublesome lubrication problems — check the advantages listed below:

1—Dispense either oil or grease.

2—Deliver a pre-determined measured quantity of lubricant to each bearing.

3—Lubricant delivered at a uniform pressure even to remote bearings.

4—Injectors are easily adjusted for the desired output—no special tools needed.

5—Each injector has external indicator.

6—Complete range of lubricant pumps ——pneumatically, electrically or manually operated.

7—Will pump lubricant from original container at fixed time intervals.

8—All pumping units are of proven design.

9—One pump can supply one machine or a battery of machines.

10—Easy to install. Only one supply line needed.

11—Injectors in manifold can be removed singly without disturbing other injectors.

12—Linpak packing —no metal-to-metal seals.

13—A product of a company that manufactures lubricating equipment exclusively.

Check these facts — compare them with other systems and you will understand why Lincoln Centro-Matic Systems are being used in all types of industrial applications.

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Lincoln Engineering Company maintains a staff of experienced lubrication engineers prepared to assist you in all lubrication problems. Write us, enclosing a blueprint or specifications of the machine you wish to lubricate and we will make a recommendation as to the type of Centro-Matic System best suited to do the job.

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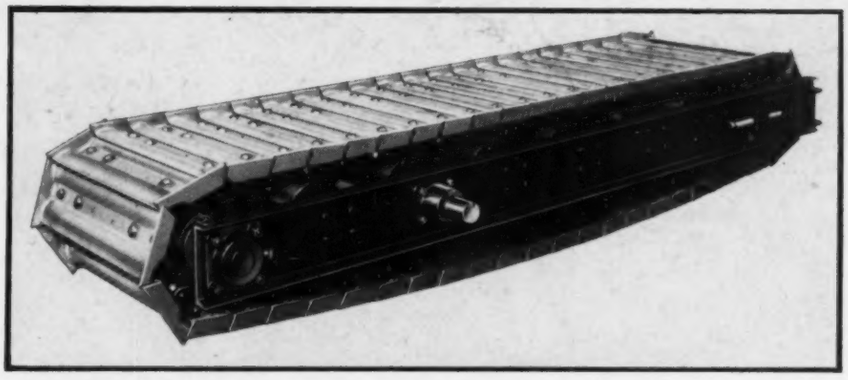
CONVEYER UNITS FOR HEAVY LUMP MATERIAL

▲ Chain Belt Company of Milwaukee announces the production of a completely self-contained factory assembled heavy-duty apron conveyor unit. The heavy-duty roller supported apron feeder is furnished in several widths and with centers ranging from a minimum of 4 ft 7 in. to a maximum of 9 ft 1 in. varied by 18 in. increments.

This type of feeder is widely used under bins and hoppers for heavy lump material such as ore and pit-run gravel and rock and has exceptionally large capacity. At a normal speed of 10 fpm, handling 100 lb material, capacities of these standard units will run up to 80 tons per hour. Because the heavy steel chain belt rides directly on large diameter traction rollers, the design of the new heavy-duty feeder means longer chain belt life, and reduced power consumption.



Conveying unit for use under bins and hoppers carries heavy lump material such as ore, gravel and rock.

IRON ORE MINE PLACES NEW EQUIPMENT ORDERS

▲ The North Wade open pit iron ore mine near Kinney, Minnesota, on the Mesabi Range will be brought into production as a joint operation by Inland Steel Company and Cleveland-Cliffs Iron Company. Orders have been placed for shovels, trucks, and other necessary equipment and stripping will commence as soon as these have been delivered. A substantial tonnage of ore will be shipped this season.

The North Wade mine was acquired by Inland late in 1945 and will be operated by Cleveland-Cliffs Iron Company under the terms of an agreement reached with Inland. Inland's present operating iron ore properties consist of four underground mines in the Michigan peninsula and in Minnesota.

TESTING UNIT GIVES INDEPENDENT READINGS

▲ The Bacharach Industrial Instrument Company is now producing a Duplex Fyrite Test Set, comprising two separate portable indicators, one for direct carbon dioxide analysis, the other for direct oxygen analysis. The instruments are packed in a compact carrying case, together with aspirator and rubber hose for connecting either to the desired sampling point.

Both instruments employ the fundamental principle of chemical absorption and therefore give readings that are independent of voltage, humidity, temperature, or atmospheric pressure conditions. Operation of each indicator is identical. The complete test with either instrument can be made in less than one minute, with an accuracy of within ½ of 1 per cent O_2 or CO_2.

CARPENTER STEEL BUILDS NEW RESEARCH LABORATORY

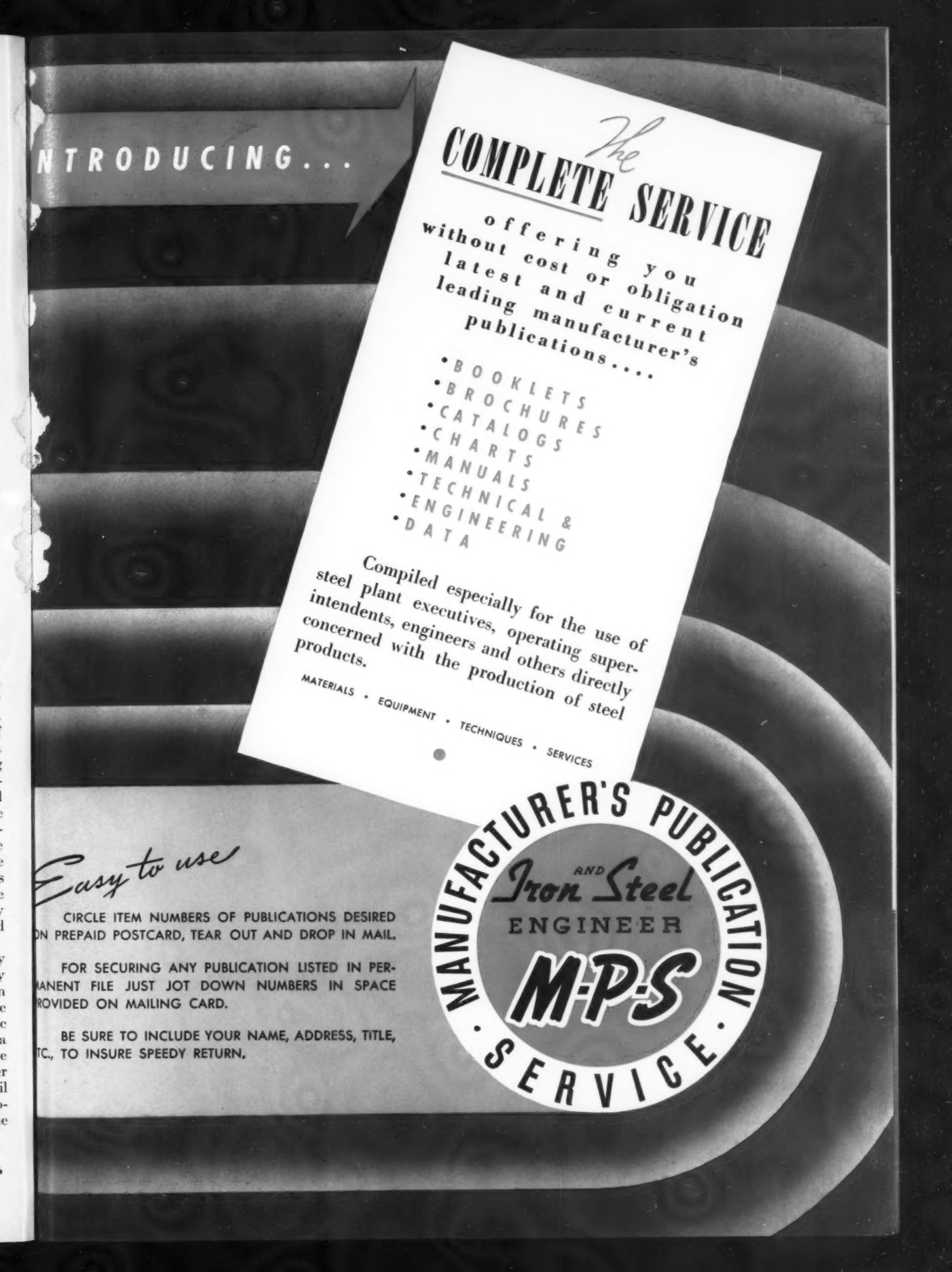
▲ To provide the very latest and most complete facilities for developing new and improved steels, and for maintaining exacting control over high quality tool, stainless and alloy steels, The Carpenter Steel Company, Reading, Pennsylvania, has announced plans for a modern, new research laboratory.

Ground has been broken at the company's mills for the new three story structure. Plans for the first floor include experimental melting and rolling equipment, a heat treating department, machine shop and physical testing laboratories. The second floor will be occupied by a complete metallographical laboratory, equipped with the most modern type of special apparatus for the study of problems affecting the behavior and performance of tool steels, stainless steels, magnetic steels and nickel alloys.

VARIABLE STROKE PUMP IS NOW IN PRODUCTION

▲ An improved variable stroke triplex pump termed the "Automatic Variflo" is now in production by the Worthington Pump and Machinery Corporation, Harrison, New Jersey. The objectives in the development of the pump have been the design of a high pressure triplex pump having stepless 0-100 per cent capacity variation, which would afford increased dependability and easier maintenance for this service. Produced in identically the same frame as used for the corresponding size of constant stroke pump it has the same dimensions except for the control cylinder on the left of the pump. This space taken by the control cylinder would be allowed clearance space, in any event.

The compactness and accessability of this pump is accomplished by locating the crankshaft at the base in the fully enclosed frame. Bearings are of the roller type. Positive, automatic pressure lubrication is provided by a direct driven gear oil pump. The stroke changing elements and other bearings are flooded with filtered oil at all times. The oil pump also provides oil pressure for operating the hydraulic stroke control cylinder.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FOR THOSE WHO MUST *KNOW* . . .

(1) Dust Control

This dust control booklet contains installation photographs, charts, and discusses the design of a Roto-Clone exhaust system. Included is an explanation of pressure relationships in an exhaust system and methods of measurement. (34 pages, 270-A). American Air Filter Company.

(2) Crane Safety Switch

A looseleaf folder announces the new No. 10 Youngstown safety limit stop, for use on either alternating or direct current crane-hoists, to prevent overtravel in the hoisting direction. The stop is of the weight-operated type and intended for use on small or medium capacity cranes. (8 pages, 1032). The Electric Controller and Manufacturing Company.

(3) Atmosphere Constituents

New information on the preparation and applications of the various types of atmospheres used in the heat processing of metals is included in a recent bulletin. Described are prepared atmospheres, nature of the constituents of various atmospheres, the effect of each and the combinations used. Costs are included. (12 pages, SC129). Surface Combustion Corporation.

(4) Rubber Tapes

Featured in a new catalog section is Goodrich "Two-In-One" tape, which weatherseals wire or cable splices in one operation in less than half the time needed for combined use of friction tape and splicing compound. A single layer provides adequate insulation for lines carrying up to 220 volts, a double layer on lines up to 650 volts. Other advantages are outlined. (4 pages). The B. F. Goodrich Company.

(5) Surface Pyrometers

The use of Cambridge surface pyrometers — roll, extension, mold, and needle models — is described in a new pamphlet. These pyrometers make possible maximum production without shortening the life of the rolls or risk of breakage. Sheet spoilage is avoided if rolls are at proper temperature before starting up. (12 pages, 194 SA). Cambridge Instrument Company, Inc.

(6) Rotocastings

Details on the engineering aspects of alloy castings, a discussion of laboratory work done by National Alloy Steel Laboratory, and a description of the technique of "Rotocasting" — the production of castings by the use of centrifugal force — are included in a new book just issued. (20 pages, 2041). National Alloy Steel Division of Blaw-Knox Company.

(7) Slide Rule Calculator

A slide rule type of calculator is available without cost to interested users, for use in determining the per cent of total heat loss in flue gas. The calculator is used after the per cent of CO_2 in the flue gas, the temperature of the flue gas, and the room temperature have been determined. The figures on the various scales are original calculations by the Hays engineering department and are dependably accurate. Hays Corporation.

(8) Safety Valve

The story of the Cochrane safety relief valve is effectively told in a new publication. The numerous applications in relief of steam, air, gas, gasoline and oil vapors, water, and other services are cited. Of special interest is the revised "Sizing Data on Relief Valves" which includes capacity and pressure rise tables for size selection. (28 pages, 4150). Cochrane Corporation.

(9) Lubricant Compound

A modern lubricant, "I.P." Leadolene, developed to meet requirements of new production methods which use increased speeds, greater pressures, and high heat conditions, is described in a new bulletin. Discussed is the need for a water repellent lubricant because of the increased use of water in rolling mill operations. (12 pages). Brooks Oil Company.

(10) Quicker Unloading

The Robins "Car Shakeout" can unload hopper-bottom cars of coal, coke, ore, minerals, and other free-flowing materials in 90 seconds with as few as two men. Particulars of this simply installed new unloading method are described in a recent catalog. (8 pages, 128). Robins Conveyors, Inc., Division of Hewitt Rubber Corporation.

(11) Sealed Power Motors

Sealed power motors for use in dusty locations, in places where there is excessive moisture, and for all applications where the conventional alternating current, totally enclosed, fan-cooled motor has been used in the past, are described in a new folder. (4 pages). The Crocker-Wheeler Division of Joshua Hendy Iron Works.

(12) Electrical Maintenance

"Care and Maintenance of Electrical Equipment" is the title of a recent booklet. Completely illustrated, this valuable source of reference gives detailed information pertaining to inspection and maintenance of safety switches, fusible and circuit breaker panel boards and switchboard units. Square D Company.

(13) Dimensional Control

"Over 7000 Ways to Control Dimensions" is a new book that illustrates many of the new ways dimensions can be more precisely controlled with ease and economy. Indicating gages are shown in all dimensional classifications for quick reference. It is an instructive book from which you can learn new gaging methods. Federal Products Corporation.

(14) Water Strainer

The "Brassert Self-Cleaning Water Strainer" is the title of a new circular which gives a description of this new water straining equipment, the capacities, the straining media, and other pertinent engineering data. This strainer will remove fine suspended particles from raw or process water, and disposes of these particles in a continuous, automatic and self-cleaning manner. (4 pages). S. P. Kinney Engineers, Inc.

(15) Grinding Wheels

"Safety Grinding Wheel Facts and Figures" is the title of a complete pocket-size publication just issued. This book describes fully the various applications to which grinding wheels can be put and their proper selection for various grinding jobs. Handy reference tables provide useful information to engineers with grinding problems. (108 pages). The Safety Grinding Wheel and Machine Company.

(16) Furnace Electrodes

Helpful pointers on the use and care of furnace electrodes are presented in a new bulletin entitled: "Handling and Proper Use of Electrodes." Topics include recommended procedures for unloading, storing and installation of electrodes in furnaces. Emphasized are the proper methods of making up joints, weakest and most troublesome of electrode assemblies. Another section is devoted to precautions that prevent excessive electrode consumption due to breakage and oxidation. (8 pages). International Graphite and Electrode Corporation.

(17) Crane Cab Cooler

A bulletin, describing a new air-cooled conditioning unit for crane cabs working over ingot molds, soaking pits, or vats where acid or other fumes are present, is now available. The self-contained unit, fitted to the top of the cab, requires only an electric power connection for its operation. The air supplied to the cab is cooled, cleaned, and constantly circulated. (515). Dravo Corporation.

(18) Pressure Regulators

The Type 2-SO Regulator, designed to regulate the ratio of pressures or differential pressures, is described in a brochure now available. The brochure contains a three-color illustration of the device which clearly shows the operation. This regulator is principally used for such applications as the control of suction, pressure or flow ratio in any gas or air flow system where accurate control is required. (1245). Hagan Corporation.

(19) Electrical Progress

A preview of the new electrical units being offered for post-war sales is given in a bulletin recently issued. Included are the equipment developments during the war years 1941-1945. (4 pages, DM 704). Motor Generator Corporation, division of the Hobart Brothers Company.

(20) Speed Reducers

"Clevelands in the Modern Production Flow" is the name of a pictorial bulletin describing the applications of worm gear speed reducers. Standard Cleveland drives are illustrated in connection with typical installation views. (4 pages). The Cleveland Worm and Gear Company.

(21) Face Milling

The new standard "Vibra-Cushioned" carbide tipped face mills expressly designed for face milling of steels is described in a new booklet. These inserted blade carbide face mills — said to represent a major

advancement in the art of milling steel with carbides, both as to performance and cost per piece produced — are ready for delivery from stock. (4 pages, FM 46). Tungsten Carbide Tool Company.

(22) Synchronous Motors

Eight of the economies and operating advantages gained by the use of synchronous motors engineered to large, constant speed industrial applications are illustrated and discussed in a newly issued folder. Gives examples of synchronous motors direct-connected to various types of drives. (4 pages, FF11). Electric Machinery Manufacturing Company.

(23) Stationary Batteries

Featured in a new catalog are storage batteries for stationary applications. Details and illustrations are given on the Gould Plante, Kathanode Glassklad, and Dreadnaught. Various characteristic discharge curves are shown and technical data is furnished covering all sizes and types used in stationary application. (1000). Gould Storage Battery Corporation.

(24) Centrifugal Pumps

Design, construction, and engineering details of the "Cameron Single-Stage" general service pump is covered in a two-color book. These pumps are suitable for a wide variety of services wherever liquids have to be handled. Capacities up to 25,000 gal per min against heads up to 300 ft. Shown are typical installations, cross-section and interior views, and various types of drives available. (20 pages, 7057). Ingersoll-Rand Company.

(25) Immersion Pyrometers

A catalog illustrating and describing the new "Pyro" immersion pyrometer is now available. The booklet describes the thermo-electric system and the construction of the pyrometer. The new instrument can be used with "bare metal" and "protected" type thermocouples, both being instantly interchangeable. (150). Pyrometer Instrument Company.

(26) Magnetic Relay

Details and circuits of the Edison "Sensitive Magnetic Relay" are covered in a new booklet available to steel mill operators. The magnetic system, which is inclosed in a highly permeable metal shield which protects it from stray external magnetic fields, is also discussed. (3004). Instrument Division of Thomas A. Edison, Inc.

(27) Hole Punching Units

Fully described and illustrated in a new issue are the new "Wales type BL" hole punching units. These unique, self-contained units have the punches, dies, stripping guides, stripping springs and guide buttons designed into a holder which automatically aligns punches and dies. Unlike the conventional type dies, nothing is attached to press ram. The only function of the ram is to depress the punch through the work. (BL). Wales-Strippit Corporation.

(28) Slide Chart

Engineers, designers, and steel mill operators will welcome a new slide chart which makes easy the calculation of velocity flow and capacities of heat exchangers. The chart contains a wealth of information and data on areas of diameters of tubes, a pressure table, and a table of weights for round stainless steel tubing. Information is also given on the principal grades of Carpenter stainless tubing. Welded Alloy Tube Division of The Carpenter Steel Company.

(29) Valves and Fittings

A recent innovation in foundry practice is described in a new folder on Cooper stainless steel valves and fittings. The folder announces a new procedure of registering stainless steel heat and analyses and stamping all castings with corresponding numbers for permanent identification. Description of the Cooper line is included which embraces standard types of globe, gate, Y, check, needle and quick-opening valves. Cooper Alloy Foundry Company.

(30) Power Brushes

A booklet designed to serve as an encyclopedia of power brush usage in manufacturing operations has just been issued. The contents of this publication include factors that enter into the selection of brushes, taking into consideration methods that should be employed to gain the greatest use from each of the wide variety of power brushes. Fifteen separate tables give detailed information on a variety of factors entering into efficient power brushing operation. (24 pages). The Osborn Manufacturing Company.

(31) Gas Alarm System

A new technical bulletin has just been issued on the "Davis Combustible Gas Alarm System." The bulletin describes the various combinations possible with this system, together with photographs showing the control panel, which is placed in a gas free area, and the explosion-proof analyzer head which detects the presence of combustible gas or vapor at point of origin. Included also is a description of the principle upon which the system operates, the method of operation, and a schematic diagram of a typical installation. (8 pages). Davis Emergency Equipment Company, Inc.

(32) Lifting Hoist,

Of timely interest is a new bulletin just issued featuring a new lightweight portable air hoist designed for a multitude of lifting jobs in the ¼ and ½ ton capacity range. The booklet, which is extensively illustrated, describes in detail the operation and mechanical construction of the new hoist which weighs only 30 pounds, but has a lifting capacity of 1000 pounds at 17 ft per min and proportionately greater speeds for lesser loads. Explanatory sections of the folder describe the variable speed features, built-in safety features and give engineering data. Keller Tool Company.

(33) Carbide Tools

A new condensed catalog presents a complete description of "Metro" standard carbide tools and masonry drills, and includes specifications and prices. (6 pages). Metro Tool and Gage Company.

(34) Air-Hydraulic Cylinders

The new standard "Air-Draulic" cylinders, together with valuable engineering data, is offered in a new brochure. These cylinders are a new development combining the major advantages of both air and hydraulic cylinders. Although powered by compressed air, they provide smooth, uniform, hydraulic-type feed control in a self-

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Products and Developments

contained oil circuit which does not require use of an hydraulic power unit. The operating principle is described in the book, which also explains how to utilize its advantages in a wide range of manufacturing and processing applications. (16 pages). Logansport Machine Company.

(35) Control Systems

Principal features of the "Micromax" round-chart temperature controllers are covered in a catalog available to iron and steel engineers. The booklet tells how these controls, and the recorded information, enable mills to operate at highest efficiency, regardless of differences in sizes of charges in soaking pits, condition of burners or any other factor. (N-33B). Leeds and Northrup Company.

(36) Ampere Control

A bulletin is available describing "Limitamp" control for safety of both men and machines. The book tells how it can be furnished as single units, and how it comes in different enclosures for different operating conditions. This control will stop high-voltage fault currents in one-quarter cycle, and clear them in less than one-half cycle — reducing the effect of the short circuit on your motor or control. (GEA-4247). General Electric Company.

(37) Speed Drives

An all-electric-adjustable-speed drive operating from a-c circuit, "Type V*S," is covered in a bulletin available to you. The book tells how unlimited speed variation with absolutely smooth acceleration and deceleration and automatic maintenance of proper tension are available. (311). Reliance Electric and Engineering Company.

(38) Carbide Dies

A new publication containing full information, prices and particulars on "Talide" tipped centerless grinder blades, wire and tube dies, sheet metal dies, extrusion and shape dies, bushings, gages, centers, and bar stock. The book also contains general engineering information in connection with the application of "Talide" metal. (36 pages). Metal Carbides Corporation.

(39) Gate Valves

Latest developments in lever-operated gate valves are covered in a new booklet, which shows industrial and process line applications for which these valves are particularly advantageous. The bulletin describes in detail the features of these valves, including their quick-action, straight-through flow, leak-tight seal and self-grinding of the sealing surfaces. (16 pages, E-150). Everlasting Valve Company.

(40) Thermocouple Data

A new edition of the "Thermocouple Data Book and Catalog" is now available. It gives information on selection of proper thermocouples and carries installation aids. Described and listed are prices and recommendations on thermocouples, thermocouple wire, lead wire, heads, connectors, plug and socket assemblies, insulators and protecting tubes. (32 pages, S2-6). Wheelco Instruments Company.

(41) Coolant Filter

A new fileter designed to remove abrasive and metallic particles from grinder coolant is described in a new catalog. (4 pages). Cuno Engineering Corporation.

(42) Precision Melting

High-speed precision melting of alloy steels and other ferrous metals in Ajax-Northrup induction furnaces is described in a new bulletin. Furnaces in sizes from 120 lb to several tons capacity, powered by efficient motor-generator units from 50 kw up are illustrated and fully discussed. (16 pages, 11-B). Ajax Electrothermic Corporation.

(43) Transformers

Completely described and attractively illustrated in a new booklet are transformers for sixteen fields of application including power circuit, mercury lamp, neon, signal, and street lighting. Included is descriptive information on ballasts, renewable and non-renewable fuses, fustats, plug fuses, and solenoids. (12 pages, 451-GB). Jefferson Electric Company.

(44) Alloy Welding Chart

A reference wall chart on alloy welding is available for mounting on your office wall. The data includes tables on corrosion resistance, on heat resistance, and on weld metal surfacing, as well as the chemistry of the weld metal. The chart is 20 in. by 30 in. Arcos Corporation.

(45) Heat Treating

Available for your own vest-pocket is a large, handy heat treating data book full of charts, tables, diagrams and other helpful material for all types of engineers. (72 pages). Stewart Industrial Furnace Division, Chicago Flexible Shaft Company.

(46) Stainless Steel

Outstanding properties of the new stainless steels are discussed in the following "Stainless Steel Data Booklets" available to you to keep you abreast of new improvements. These stainless steels are for applications requiring corrosion and heat resistance. (32, 33, 34, and 35). Timken Roller Bearing Company.

(47) Wire Rope Slings

The complete line of Macwhyte wire rope slings, with application pictures and helpful sling information, is covered in two catalogs prepared for you. (S-7 and 44-1). Macwhyte Company.

(48) Sleeve Bearing Rule

A handy sleeve bearing slide rule that enables you to determine at a glance if your bearings are standard stock sizes is now obtainable. Johnson Bronze.

(49) Worm Gears

A publication describing the various advantages of "De Laval" gears is available. These gears are widely used on blast furnace and steel mill equipment, including billet pushers, catcher tables for three-high mills, cooling table transfers, crane trolleys, furnace door lifters, hot beds, ingot buggy drives, manipulator tables, piler tables, plate shears, roll grinders, screwdowns, etc. The book tells how these worms and gears are supplied either separately or complete with bearings and casings. (W-1135). De Laval Worm Gear Division of the De Laval Steam Turbine Company.

(50) Materials Handling

Just released is a new folder illustrating trucks, platforms, pallets, racks, work table, box and barrel grabs and other equipment for every type of materials handling operation. (4 pages). Palmer-Shile Company.

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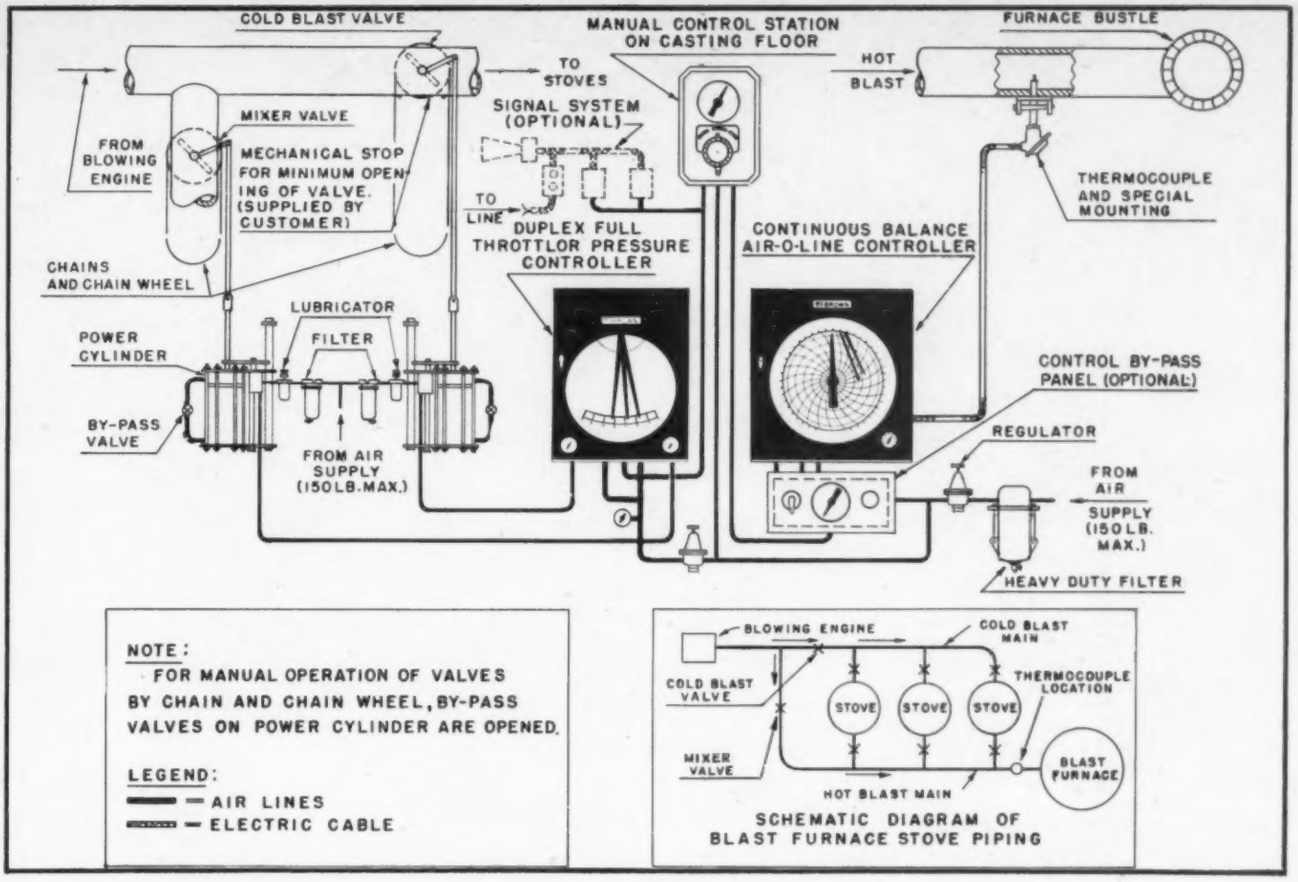


Brown Hot Blast Control System

CONTROL BLAST FURNACE TEMPERATURES with "Continuous Balance" PRECISION

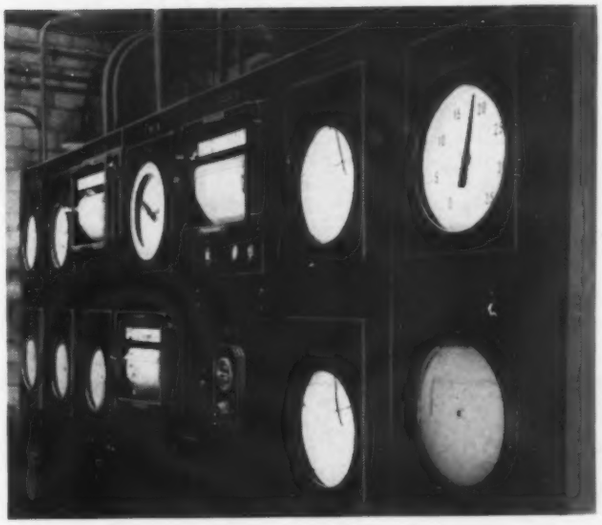
For highest tonnage rates and finest metallurgical quality, continuous control of blast furnace operation is imperative.

AUTOMATIC HOT BLAST CONTROL — Brown *ElectroniK* Air-O-Line Controllers maintain continuous control of hearth emperatures during stove changes. *All* blast conditions are maintained more precisely with the *ElectroniK* operating on the "Continuous Balance" principle which uses, instead of a galvanometer, an electronic detecting unit which provides *continuous* temperature measurement and control with greater accuracy and ruggedness.

STOVE TEMPERATURES — Brown *ElectroniK* Recorders make possible increased checker life and lower gas consumption through signalling or control systems applied to dome and stack temperatures.

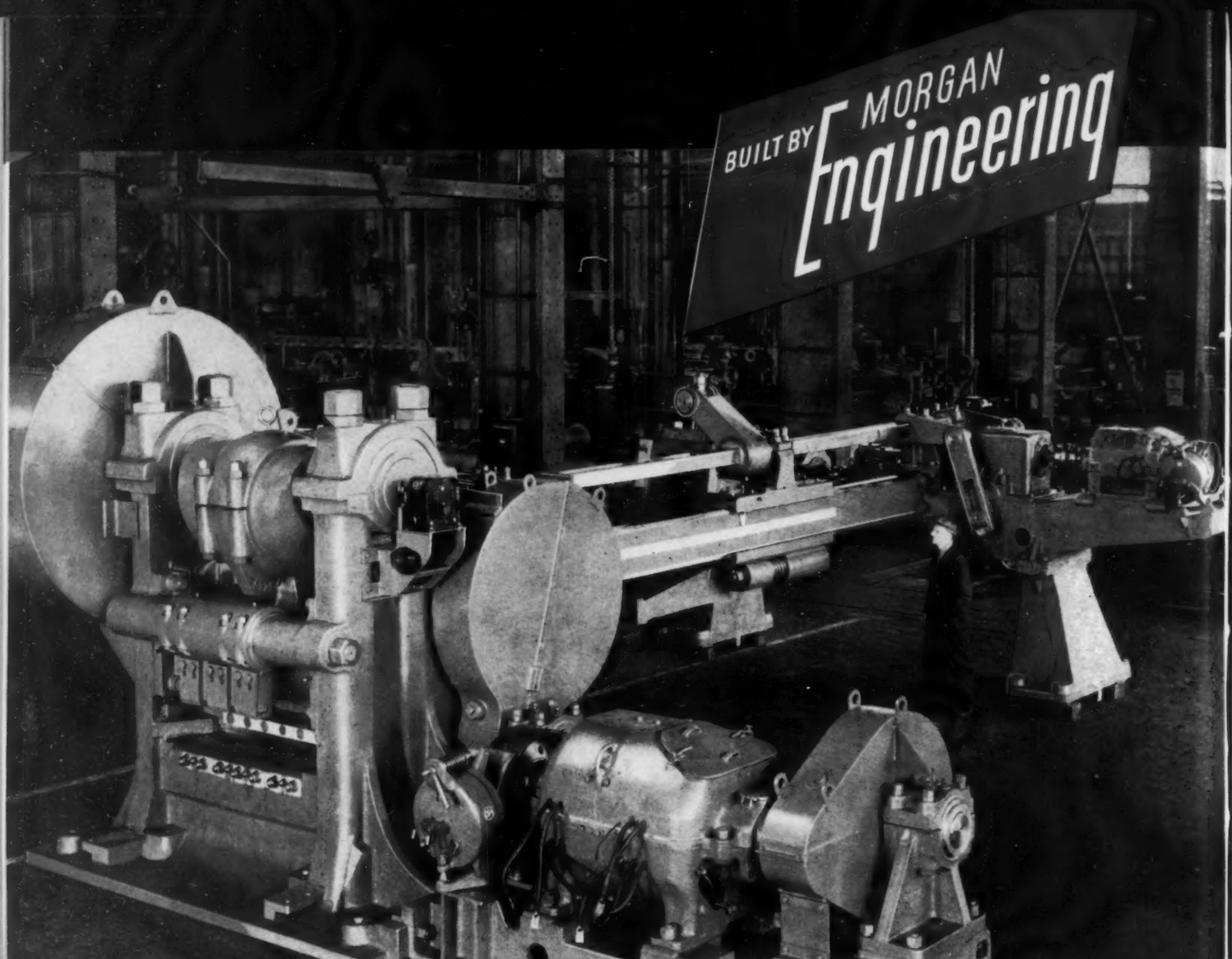
GAS CLEANING — Brown Thermometers, Pressure Gauges and Flow Meters, by measuring and controlling conditions through Dust Catchers, Gas Washers and Precipitators, provide clearer gas with lower water consumption.

THE BROWN INSTRUMENT COMPANY, a division of Minneapolis-Honeywell Regulator Co., 4464 Wayne Avenue, Philadelphia 44, Pa. Offices in all principal cities. Toronto, Canada; London, England; Stockholm, Sweden; Amsterdam, Holland.



Brown Instruments on a panel board in a nationally known steel mill.

BROWN *Electronik* POTENTIOMETERS



MORGAN 450-TON BLOOM AND SLAB SHEAR

● Among the many types of mill equipment built by Morgan, is the 450-Ton Bloom Shear illustrated above for shearing 12″ x 12″ blooms and equivalent slab sections. Shear is designed without flywheel or clutch for start and stop operation. Hold-down gag is of the independent hand adjusted type. A motor operated gauge is provided for gauging lengths from 2′0″ to 15′0″. Of massive construction, this shear is typical of the types of mill equipment Morgan designs and builds.

THE MORGAN ENGINEERING CO.
ALLIANCE, OHIO. 1420 Oliver Building, Pittsburgh

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Personnel News

Albert J. Hulse, formerly with Carnegie-Illinois Steel Corporation at Pittsburgh, has joined The Youngstown Sheet and Tube Company as chief engineer. He succeeds **J. D. Jones** who left the company about a year ago.

Mr. Hulse, a native of Washington, D. C., was in Officers' Training School when World War I ended. He came to the Youngstown district in 1925 as chief draftsman for Trumbull Steel Company in Warren, after serving as draftsman for several steel companies. Later, he became assistant chief engineer for the H. A. Brassert Company, consulting engineers of Chicago.

In 1935, he went with Carnegie-Illinois Steel Corporation as assistant chief engineer at their South Chicago Works, and was appointed chief engineer a short time later. A few weeks before Pearl Harbor, he was transferred by United States Steel Corporation to Columbia Steel Company to fill the position of chief engineer on the construction of Geneva Steel Works for the United States Government at Provo, Utah, the largest of wartime steel expansion projects. Upon completion of the Geneva project, he returned to Carnegie-Illinois as senior staff engineer in the Pittsburgh Office.

Milton T. Satter will be associated with the roll sales division of the Aetna-Standard Engineering Company of Youngstown, Ohio, as roll engineer. Mr. Satter is not a newcomer to Aetna-Standard as he has been employed in various positions with the company during the past four years.

Erwin Loewy, president of Hydropress, Inc., after having completed a special mission of nine months in Germany for the United States Government, has returned to his desk.

Alvin F. Franz was recently made works manager of the Pueblo, Colorado plant of the Colorado Fuel and Iron Corporation. Mr. Franz, well known in the steel industry, has been general superintendent of the Buffalo plant of Wickwire Spencer Steel, a division of C. F. & I. Before his association with Wickwire Spencer, he was general superintendent of the Alan Wood Steel Company, Philadelphia, Pennsylvania, and open hearth superintendent, Otis Steel Company, Cleveland, Ohio. Mr. Franz will make his headquarters at Pueblo, Colorado.

JAMES R. SCOTT

James R. (Bud) Scott has returned to the staff of the Iron and Steel Engineer and other Association publications after serving three years in the Air Force of the United States Army. He was stationed in the Phillipine area for a considerable portion of this time.

G. Gordon Lloyd was appointed general superintendent of the Buffalo plant of Wickwire Spencer Steel. Mr. Lloyd is well known in the steel industry and has been general superintendent of the Clinton, Massachusetts plant of Wickwire Spencer since 1944. Previously, he was power and fuel engineer for the Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania.

In his new position, Mr. Lloyd will be in charge of all production at Buffalo, including Wickwire Spencer open hearth, hot mills and wire departments.

Will L. Corbett was appointed superintendent of industrial relations, Waukegan works, American Steel and Wire Company.

Mr. Corbett, a resident of Waukegan, began his company service in the yard department at Anderson, Indiana, works in 1915. Subsequently, he moved through the operating department at that plant in various jobs. He was promoted to employment supervisor at Anderson in 1926 and a year later became foreman conference leader for all American Steel and Wire plants in the Chicago district.

ALBERT J. HULSE

MILTON T. SATTER

ERWIN LOEWY

WILL L. CORBETT

If You Want to Slash METAL CUTTING & TRIMMING COSTS FROM DOLLARS TO PENNIES

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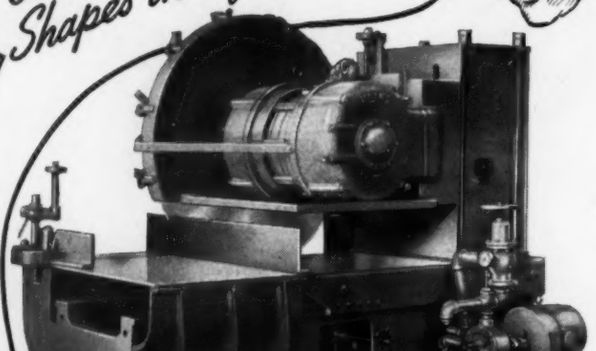
KLING Friction Saws Cut All these Bars and Shapes in a few Seconds



NO CHANGE OF BLADE OR SET-UP NECESSARY

24" 100# I-BEAM 28 SECONDS

15" 55# CHANNEL 15 SECONDS

8"x8"x343# H-BEAM 10 SECONDS

9 SECONDS 100# A.R.A. RAIL

5 SECONDS 6½"x6½"x19.8# TEE

11 SECONDS 8"x8"x¾" ANGLE

10 SECONDS 3" SQUARE

15 SECONDS 4" ROUND

11 SECONDS 6" O.D. TUBE ½" WALL

INCREASES PRODUCTION...

CUTS ALL CLASSES OF STEEL - QUICKLY AND ECONOMICALLY

The versatile ability of the Kling Friction Saw to cut varied structural shapes in any sequence, without change of blade or set-up, permits one machine to handle various types of work which, otherwise, would require several slow speed saws to handle.

The installation of a Kling Friction Saw will quickly convince you of its superiority and advantages over the old type of saw. Furthermore, you will cut your cutting costs — savings will be effected in time and labor because of speed and efficiency of the Kling Saw.

GET COMPLETE INFORMATION

CONSULT KLING ENGINEERS REGARDING YOUR CUTTING PROBLEMS. WRITE FOR BULLETIN No. 9200 GIVING VALUABLE INFORMATION. SENT WITHOUT COST OR OBLIGATION.

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What is YOUR Flexible Coupling Problem?

Is it complicated by exposure to moisture, rain, dirt, grease, corrosive fumes, temperature changes? Do you require a *sparkless coupling?* THERE IS AN L-R FOR YOUR NEEDS.

L-R Flexible Couplings correct for misalignment, endwise displacement, drag, shock, backlash, etc. *Quiet.* Type "A," shown, for best service with machines with light loads, pumps, washing machines, small displays, stokers, dairy machinery, etc. Couplings up to 2500 H.P. REQUIRE NO LUBRICATION — MINIMUM SERVICING. Write today for Quick Finding Selector Charts and Complete Catalog.

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H. MILLE

H. MILLERMASTER

C. W. KUHN

C. T. EVANS

W. G. RITTER

Mr. Corbett came to Waukegan works eight years ago as personnel supervisor, and was made assistant industrial relations supervisor in 1940, the position he held prior to his new appointment.

Walter L. Longnecker has been appointed division superintendent of the rod mills in the Cuyahoga Works of the American Steel and Wire Company, a United States Steel subsidiary, in Cleveland, Ohio.

Mr. Longnecker, a native of Erie, Pennsylvania, joined the company in 1939 at its Donora plant following his graduation from Worcester Polytechnic Institute, at Worchester, Massachusetts. In 1944 he became general foreman of the rod mills at Donora, Pennsylvania, and in June 1945 he was made division metallurgist, rod mills with offices in Cleveland, Ohio. He is a member of the Association of Iron and Steel Engineers.

Albert A. Highley has recently accepted a position as superintendent of the roll department, Carpenter Steel Company, Reading, Pennsylvania. Before coming to the Carpenter Steel Company, Mr. Highley was employed as superintendent of the roll shop of the Brigham Road plant of the Allegheny Ludlum Steel Company, Dunkirk, New York. Mr. Highley had been with the Allegheny Ludlum Steel Company for twenty-seven years.

John J. Alexander, assistant superintendent, power department Corrigan-McKinney plant, Republic Steel Corporation, recently was awarded the **John E. Johnson, Jr.** award of the American Institute of Mining and Metallurgical Engineers. This award was presented because of Mr. Alexander's successful efforts in developing a method of connecting two turbo blowers in series in order to blow 100,000 cu ft per min of wind at high pressure and for his work on adding a controlled amount of moisture to the blast.

David W. R. Morgan, manager of the steam division of the Westinghouse Electric Corporation, has been appointed general manager of the entire South Philadelphia Works. Mr. Morgan's responsibilities will include general supervision of the aviation gas turbine division, and the Attica, New York, plant of the stoker department. He will retain direct management of the steam division.

Mr. Morgan has been manager of the steam division, which builds steam turbines and associated equipment for electric power generation and marine propulsion, since February, 1944. During the war, the division produced more than 41,000,000 horsepower of turbines, including the propulsion machinery for all the U. S. Navy's 27,000-ton Essex class aircraft carriers.

Born in Martins Ferry, Ohio, in 1892, Mr. Morgan studied mechanical engineering at Ohio Northern University, from which he was graduated in 1913.

C. T. Evans was recently appointed consulting engineer on the research and development staff of Cutler-Hammer, Inc., Milwaukee, Wisconsin. Two other appointments were made to the staff and **C. W. Kuhn** was made assistant manager of developments and **R. A. Millermaster** was also made assistant manager of developments. These three men have been members of the Cutler-Hammer development department for many years and are intimately acquainted with the products and duties for which they are now responsible.

Mr. Evans received his technical education at Ohio State University graduating in 1908. He joined Cutler-Hammer shortly after graduating and has been with them ever since. Mr. Evans has specialized in electric motor control and has over sixty patents in his name. Mr. Kuhn graduated from the University of Cincinnati in 1923, when he joined Cutler-Hammer where he has spent all but two years in the development department. He also has done work on motor control. Mr. Millermaster graduated from the University of Wisconsin in 1927 and has been with Cutler-Hammer since that time. Mr. Millermaster's work has been chiefly in the field of appliance and tool handle switches, industrial safety switches, service control equipment, multi-breakers, molded insulation and aircraft electric equipment.

Wayne G. Ritter is now associated with F. R. Magill, who is distributor and agent in Western Pennsylvania for the Trabon Engineering Corporation, Chicago Rawhide Manufacturing Company, Union Chain and Manufacturing Company, Gerotor May Corporation, and Spraying Systems Company.

Mr. Ritter, who was released from the Army with the rank of Colonel in the Corps of Engineers, recently returned from European service. After his graduation from Colorado School of Mines in 1936, he was employed by the Youngstown Sheet and Tube Company in their metallurgical and blast furnace departments. Prior to the outbreak of war he was in the engineering department of the Carnegie-Illinois Steel Corporation.

Kenneth A. Moody has been appointed training director of the American Steel & Wire Company, a United States Steel subsidiary. Mr. Moody was identified with personnel and training education in the company from 1937 until his departure for military service in December, 1943. He was discharged from the

(*Please turn to page 112*)

MOTOR BURNOUTS

can be prevented by protecting MOTORS with FUSETRONS

Fusetrons have a tremendous time-lag. Thus, on normal installations, they can be used in a size near to the actual running current of the motor without opening on motor starting current or other harmless overloads.

When so used, Fusetrons protect motors from ANY harmful excess of current—caused by such things as being stalled, lack of oil, worn bearings, tight belt, overloading, wrong voltage or SINGLE PHASING.

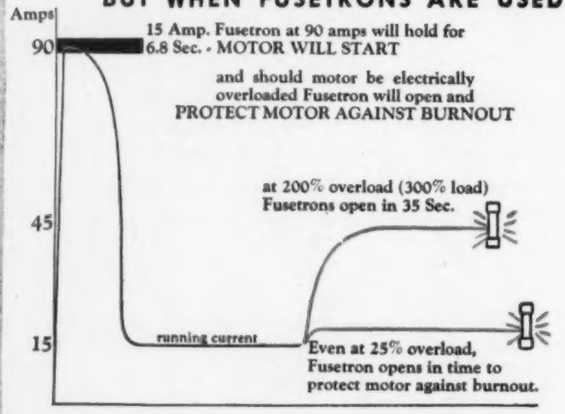
Ordinary Circuit Protective Devices Cannot Protect Motors Against Burnout

Such devices do not have sufficient time-lag, when used in motor-running protection size, to hold the motor-starting current. For example:

The starting current of a 15 amp. A. C. motor is 90 amps. or more, enough to blow an ordinary 15 amp. fuse in about 1/10 second, or a 15 amp. ordinary breaker in about 2½ seconds. In either case, the circuit would be shut down before the motor could get up to speed.

To permit a motor to start a 35 amp. breaker or a 45 amp. fuse would commonly be used. Then an excess current of from 133% to 200% of the motor rating could cause the motor to burn out—without opening the protective device.

BUT WHEN FUSETRONS ARE USED


Amps
90
45
15
15 Amp. Fusetron at 90 amps will hold for 6.8 Sec. - MOTOR WILL START
and should motor be electrically overloaded Fusetron will open and PROTECT MOTOR AGAINST BURNOUT
at 200% overload (300% load) Fusetrons open in 35 Sec.
running current
Even at 25% overload, Fusetron opens in time to protect motor against burnout.

Thus any motor from 1/10 to 500 amp. size can, on normal installations, be protected by Fusetrons if used in motor-running protection size.

Fusetrons Give DOUBLE Protection to Large Motors. Of course, larger motors are protected with thermal cutouts or overload relays. They save many motors—but experience shows that such devices sometimes fail to operate and a motor burns out.

By replacing fuses used for short-circuit protection with Fusetrons of MOTOR-RUNNING protection size, you get the same short-circuit protection PLUS DOUBLE PROTECTION against motor burnout from single phasing or any other cause.

Fusetrons will act INDEPENDENTLY to SAVE THE MOTOR. There is nothing to stick, nothing to go wrong. They cannot be reset nor can corrosion or dirt lengthen their blowing time. When the solder in the thermal cutout melts the circuit is open—there is no way it can be held in or jammed.

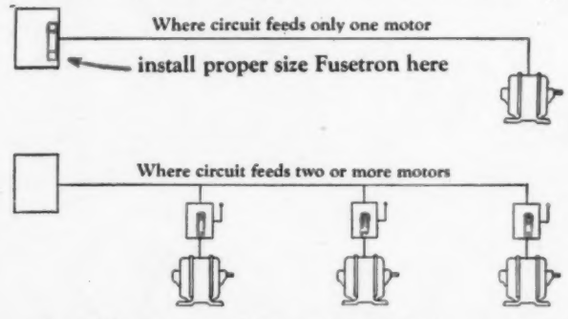
Fusetrons provide simplest way to prevent damage from Single Phasing. When single phasing occurs the current flowing through motor and through Fusetrons in the remaining phase increased about 100%. (Theoretically 73% but change in efficiency and power factor makes it about 100%).

This 100% overload on Fusetrons of MOTOR-RUNNING protection size opens them and STOPS FLOW OF CURRENT to the motor.

Never before has such dependable single phasing protection been available to prevent motor burnouts.

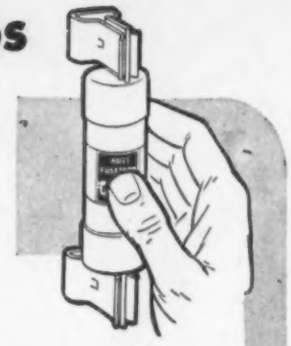
Fusetrons make protection of SMALL Motors against burnout, simple and inexpensive. Heretofore, SMALL motors have often been left unprotected because the cost of protection has been too great compared to the cost of replacing the motor. Yet a burnout means replacing the motor—PLUS the loss of labor and production.

Now look how simple it is to avoid such losses . . .



Install Fusetron in switch or fuse block to protect each individual motor . . . or on portable tools or devices, install Fusetron in attachment plug or connector or in a fuse block attached to device.

A Fusetron turns any set of fuse clips into a Motor Protective Device . . .



. . . as accurate, as safe and as dependable as any device on the market; regardless of cost. Fusetrons have the same degree of approval for both motor-running protection, under National Electrical Code and Underwriters' Laboratories Standards, as do the most expensive devices made.

WHAT IS THE FUSETRON?

The Fusetron is a DUAL element device—A Fuse to which is added a Thermal Cutout.

The result is a fuse with tremendous time-lag and much less electrical resistance.

Fusetrons have the same degree of Underwriters' Laboratories' approval for both motor-running and circuit-protection as the most expensive devices made.

Fit standard fuse blocks

Fusetrons are made to same dimensions as ordinary fuses and fit all standard fuse holders.

They are obtainable in all sizes from 1/10 to 600 ampere—in both 250 and 600 volt types.

Also obtainable in plug type and Tamper-resisting type (Fustats) for 125 volt circuits.

Their Cost is Surprisingly Low

Says a Nationally Known Consulting Engineer

"We recommend Fusetrons to all our clients because we have found them superior to any other device to protect motors against burnout.

"Here's an illustration of our experience with Fusetrons.

"One of our filling station clients reported by telephone that his compressor was not operating. Our Mr. Hrastich called and found that Fusetrons in the circuit had blown. With new Fusetrons installed, the compressor operated for 3 minutes, then slowed down and the Fusetrons blew. Inspection showed that the bearings of the motor were dry. When the bearings were oiled, the motor operated without any difficulty.

"The client could see for himself that the Fusetrons had saved him a burned-out motor, a major shutdown and a repair bill."

H. J. Brandenburger
Carleton B. Fox Company,
St. Louis, Missouri.

INSTALLED THROUGHOUT THE ENTIRE ELECTRICAL SYSTEM, FUSETRONS GIVE MANY KINDS OF PROTECTION HERETOFORE NOT AVAILABLE

Fusetrons do everything fuses do. They open on harmful overloads and on short-circuits stop the flow of current quickly and safely, all of which is confirmed by the Underwriters' Laboratories Label . . . and in addition you can

★ ***Entirely wipe out needless blows caused by motor starting currents or other harmless overloads.***

Fusetrons have tremendous time-lag. They hold 500% load more than 10 seconds whereas most sizes of ordinary fuses blow in less than one second. They won't open on starting currents or harmless overloads (heavy overloads for a short time or light overloads for a longer time). Fusetrons won't shut down a circuit needlessly. They open only when something goes wrong.

★ ***Give Thermal Protection to Panelboards and Switches***

The thermal cutout in the Fusetron will open whenever its temperature reaches 280° F. Thus if poor contact heat develops from any cause the Fusetron cuts off the current before damaging temperatures can be reached.

Ordinary fuses can't so protect because the temperature of the link must reach 786° F. before it will melt out.

With Fusetrons you are warned that a minor maintenance job is needed instead of having panel or switch damaged or destroyed by poor contact.

★ ***Prevent Needless Blows caused by Heating in Panels and Switches***

Fuses have 55 to 140% greater electrical resistance at full load than Fusetrons, hence Fusetrons produce less heat than any fuses. They operate cooler and eliminate useless shutdown troubles caused by fuses running too hot.

★ ***Permit use of larger motor or adding more motors on circuit WITHOUT installing larger switch or panel***

The operating load on Fusetrons can be close to their ampere rating because Fusetrons hold starting currents. But ordinary fuses must be installed oversize because they lack sufficient time-lag to hold starting currents

By replacing oversize fuses with Fusetrons, you can load panels or switches near their capacity. A larger motor or additional motors can be installed without the trouble or expense of changing the panel or switch.

★ ***On new installations, PROPER size switches and panels can be used instead of OVERSIZE***

With ordinary fuses, switches and panels must be oversize because fuses larger than the operating load must be used to hold starting currents.

But Fusetrons hold starting currents, therefore, PROPER size switches and panels to fit the load can be installed, saving money and space.

★ ***Protect motors against burnout*** (See opposite page)

★ ***Protect Coils, Transformers and Solenoids against burnout***

Install a proper size Fusetron. It won't open on harmless overloads of normal current surges, yet should a dangerous overload occur for any reason it will cut off the current to prevent a burnout.

BEFORE YOU MAKE ANY CHANGES OR START ANY NEW WORK

GET ALL THE FACTS—CHECK THE COSTS
USE THE COUPON

Even one lost motor or one needless shutdown or one destroyed panel, may cost you more than replacing every fuse with a Fusetron. Don't risk such losses, change over the whole plant to Fusetrons at once.

BUSSMANN MFG. CO., University at Jefferson, St. Louis 7, Mo. (*Division McGraw Electric Co.*)
Please send me complete facts about BUSS Fusetrons.

Name_____
Title_____
Company_____
Address_____ State_____
City_____

I.&S.E. 446

BUSS FUSETRONS

First Fifty Years of

NON-FLUID OIL

April 21, 1896-1946. As we celebrate our fiftieth anniversary of lubrication service to industry, the factors which contributed so greatly to our development come to mind — like so many footprints on the sands of time.

While we are grateful for the advancements in industry that favored our first fifty years of growth, we feel a special gratitude and loyalty to the many companies who for so many years — either as customers, suppliers or technical collaborators — supported our efforts. These associations invaluably enriched our experience, and aided our efforts to achieve our present high standing in industry.

We begin our Golden Anniversary better equipped than ever to serve industry. We have no reconversion problems because our war efforts were concentrated solely on the expansion and production of NON-FLUID OIL. We stand on the threshold of a new era — one that we hope and pray will also be the "Golden Age of Man."

WAREHOUSES

Chicago, Ill. - Atlanta, Ga. - St. Louis, Mo. - Detroit, Mich.
Providence, R. I. - Greenville, S. C. - Charlotte, N. C.

NON-FLUID OIL
TRADE MARK REGISTERED

NEW YORK & NEW JERSEY
LUBRICANT CO.
292 MADISON AVENUE, NEW YORK 17, N.Y.

(*Continued from page 109*)

service in January of this year and has returned to the company in a newly created position as director of training for all American Steel & Wire Company plants.

W. D. Ligon was made works manager of the new Buffalo plant of the Westinghouse Electric Corporation into which the motor division is moving from East Pittsburgh, Pennsylvania.

During the time necessary to completely shift the division's operations from Pennsylvania, Mr. Ligon will act as resident Manager of the Buffalo plant. Since December, 1943, Mr. Ligon has been manager of manufacturing in the motor division with headquarters in East Pittsburgh, Pennsylvania.

Born in Pamplin, Virginia, Mr. Ligon attended Blackstone Military Academy, Blackstone, Virginia, and Virginia Polytechnic Institute, from which he was graduated in 1929 with a degree of bachelor of science in industrial engineering.

He joined Westinghouse in August, 1929, as a graduate student, then served successively as assistant foreman, time and motion study analyst and general foreman.

Franklin L. Snyder has been appointed engineering manager of the Sharon transformer division of the Westinghouse Electric Corporation.

Mr. Snyder, a native of Martinsburg, Pennsylvania, has been employed by Westinghouse since graduation from Gettysburg College in 1923. He joined the transformer division in 1925 as a design engineer, and five years later was made section engineer.

A year ago, Mr. Snyder was awarded the Order of Merit, highest honor conferred by Westinghouse on employes for outstanding contributions to the electrical industry. The citation was for his inventive ability, as shown by his contributions toward the development of voltage regulators, tap-changing-underload mechanism for transformers, the completely self-protected power transformer, and the packaged power idea for distribution stations; and for his administrative ability, particularly in handling new developments and large production contracts for ordnance.

A. E. Grapp was elected chairman of the board of directors of the Despatch Oven Company. As founder of the company over 44 years ago, he has seen the steady growth of his organization from a small one-room, one-man company to one that now occupied over 70,000 square feet of manufacturing and warehouse space employing over 250 persons. Back in 1913, the company was incorporated and Mr. Grapp was made president and treasurer, a position he has held up to this time.

H. L. Grapp was elected to the office of president and general manager. Son of the founder of the company, he is well qualified to assume the responsibilities of his new office as he has been working over 28 years on practically every machine in the factory and has occupied every executive office.

F. H. Faber was elected executive vice president and general sales manager. Mr. Faber is a typical example of the company's policy of picking its executives from within its own ranks. Starting with the company in 1928 as a stenographer, he worked steadily up through the engineering and sales engineering departments.

G. M. Lund, was made vice president and secretary. Mr. Lund came with the company eight years ago as purchasing agent; was promoted to comptroller and later made secretary.

O. J. Richardson has been appointed industrial manager of the Brown Instrument Company division of Minneapolis-Honeywell Regulator Company at Detroit, Michigan. Mr. Richardson has been with the Brown Instrument Company for the past 10 years, having served as sales engineer and in other capacities at the Philadelphia company's Cincinnati, Buffalo and Pittsburgh branches.

George W. Brown has been appointed industrial manager of the Cincinnati office of the Brown Instrument Company division of Minneapolis-Honeywell Regulator Company. Mr. Brown has been with the Philadelphia industrial division for the past nine years as sales engineer in Chicago, Louisville, Philadelphia and New York.

Frank Weir has been appointed district sales manager of the St. Louis district sales office, of the Harbison-Walker Refractories Company, 1325 Ambassador Building, St. Louis, Missouri. **Karl W. Sieling** has been appointed district sales manager of the Houston district sales office, 310 Niles Esperson Building, Houston, Texas. Both Mr. Weir and Mr. Sieling have served the company for a number of years as representatives and are well known.

H. Malcolm Priest was recently appointed manager of the railroad research bureau, United States Steel Corporation subsidiaries.

Mr. Priest will supervise research and design in the field of light-weight railroad equipment and other mobile structures, through the application of low-alloy, high strength steels produced by the corporation. The subsidiaries he serves are: Carnegie-Illinois Steel Corporation, Columbia Steel Company, National Tube Company and Tennessee Coal, Iron and Railroad Company.

Mr. Priest joined the United States Steel railroad research bureau in 1933 after ten years as a designing engineer for American Bridge, during which time he was active in the pioneer development of welded steel structures in this country.

H. MALCOLM PRIEST

OHIO

Maximum Lift MAGNETS

A standard 65" Ohio Magnet Lifting 5200 lbs. of Pig Iron

Standard round general purpose Ohio magnets are built in sizes from 12" to 65" in diameter.

Average lifting capacity for pig iron or scrap ranges from 200 lbs. to 6200 lbs.

Depending upon the amount of material to be handled, the largest suitable magnet will do it most economically.

Labor cost per lift is the same whether the lift be 200 lbs. or 6200 lbs.

THE OHIO ELECTRIC MFG. COMPANY

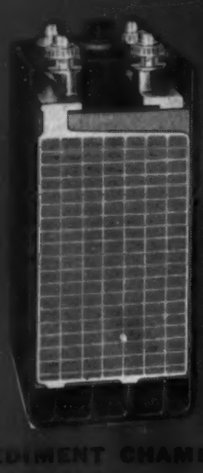
5907 Maurice Ave. Cleveland 4, Ohio

Do you have RESERVE POWER for *Emergencies?*

Gould Kathanode power gives your electric trucks the ability to meet unexpected situations. In an emergency there is power for sustained speed or for adding another load or two during a busy day.

In a Gould Kathanode battery the extra protection of the famous Kathanode Unit minimizes active-material losses. A smaller sediment chamber is practical. This means larger plates, actually a larger battery in the same over-all size container. Under ordinary conditions a Gould Kathanode does not work at full power. In an emergency you can depend on it for reserve power.

Write Dept. 44 for Catalog 100 on Gould Kathanode Glassklad Batteries for Industrial Truck and Tractor Service.



SEDIMENT CHAMBER
Kathanode-Unit protection permits larger plates and greater working capacity in the same over-all size battery.

GOULD STORAGE BATTERY CORPORATION, Depew, N. Y.

Factories: Atlanta • Boston • Chicago Dallas • Depew • Leavenworth • Los Angeles • Nepa Bergen • Rock Island Saint Paul • Salem • Sioux City Zanesville

GOULD
GLASSKLAD CONSTRUCTION
KATHANODE

J. B. CONNALLY

FRANK J. KOHUT

ROY W. SEXTON

ED T. LANDGRAFF

J. B. Connally, manager of purchases and traffic of the Mesta Machine Company retired from active service on March 15, 1946. He has been employed continuously by the Mesta Machine Company for the last forty-three years. He first came to Mesta in a clerical capacity and ten years later was appointed to the position from which he is now retiring. Mr. Connally will be succeeded by **Russell Clarkson** who has been associated with the company in various capacities for the last twenty-nine years.

Frank J. Kohut has been promoted from sales-engineering supervisor to the post of sales manager at The C. M. Kemp Manufacturing Company, Baltimore, Maryland. Mr. Kohut first joined the Kemp organization six months ago to tackle the specific assignment of improving and enlarging sales-engineering service to the metal, chemical, oil refining, printing, textile and other industries which utilize the company's systems for process heating, gas generation, and gas and liquid desiccation.

Mr. Kohut assumes his new responsibilities with unusual background, having had broad experience in both engineering and development, as well as in sales, in the chemical process and rayon industries. His ingenuities have won him acknowledgment for outstanding contributions in the synthetic chemicals field.

Ed T. Landgraff hsa been made a member of the Chiksan Company's sales staff with headquarters in New York City. Mr. Landgraff has been connected with Oil Well Engineering Company for the past 20 years, and the last three years as American representative. He is widely known in the petroleum industry, particularly among export men. In addition to sales to the domestic market in the New York territory, Mr. Landgraff will serve as eastern representative of Chiksan Export Company.

Roy W. Sexton will be with Mr. Landgraff in the Chiksan New York office at 50 Church Street, New York 7, New York. Mr. Sexton has been a member of the Chiksan sales staff for the past three and a half years.

Theodore G. Hughes has been made factory manager of Norma-Hoffmann Bearings Corporation, Stamford, Connecticut, succeeding **P. Butchard,** who has been filling the position temporatily. Mr. Hughes was formerly superintendent of the SKF Gwynedd plant number 4, at Lansdale, Pennsylvania.

Harry Wilson, Jr., formerly vice president in charge of operations, has been elected first vice president of the Jessop Steel Company, Washington, Pennsylvania, manufacturers of electric melted specialty steels.

Mr. Wilson has been associated with the Jessop Steel Company for the past 40 years in various capacities, namely general superintendent, works manager and vice president in charge of operations.

Walter F. Green has been promoted to assistant manager of the Timken Roller Bearing Company's division of research and development while **Joseph M. Roshong** has been named superintendent of the division of research and development. **Harley J. Urbach** has been appointed works engineer, taking over the former duties of Mr. Green. All three appointments were effective March 25.

Mr. Green started with the Timken organization in January, 1935, as a tool designer in the former experimental department. Later he was transferred to the works engineering department as a machine designer. In May, 1941, Mr. Green was promoted as assistant to **C. M. Maratta,** chief works engineer, and held that position until his present appointment. He received his education at the University of Cincinnati.

Mr. Roshong started working for the company in February, 1923, in the engineering department. In 1935, he began working in the former experimental department.

Mr. Urbach came to the company in August, 1933, after being graduated from the University of Nebraska at Lincoln. He started in the railroad engineering department and later was transferred to the fuel injection equipment division of the engineering department. In 1940 Urbach was transferred to the works engineering department.

F. R. MacFadyen has been transferred from the Milwaukee office of the Canton engineering department of The Timken Roller Bearing Company as industrial engineer in which capacity he will act as assistant to **S. M. Weckstein** and **Paul Haager.**

A graduate of Cornell University in 1935, Mr. MacFadyen began working for the company in 1935 and spent two and a half years in the industrial sales training program. He then was transferred to the company's St. Louis office as industrial sales engineer and later served in the Houston office in the same capacity. During the war Mr. MacFadyen assisted in the plant expansion program at Canton.

J. S. Tatman was elected chairman of the board and **John Avery** was elected as president and general

BOWSER
ESTABLISHED 1885

AUTOMATIC SELF-CLEANING FILTERS

for

STEEL MILLS
and other
INDUSTRIAL PLANTS

LUBRICATING OILS . . . . . .

. . . are efficiently filtered by the Fig. 822. Completely automatic self-cleaning saves labor and reduces downtime. Especially suited for long and continuous filtration cycles or where high capacity is required. Accommodates from two to six filtering elements. Porosities .002 to .006 of an inch, capacities 60 to 360 g.p.m.

COOLANTS . . . . . .

. . . are filtered with the Fig. 823. Special filtering medium for the removal of chips and abrasives. Porosities .002 to .045 of an inch, capacities 400 to 1200 g.p.m.

GENERAL PURPOSE UNIT . . . . . .

Fig. 824 handles a variety of filtering jobs up to 50 g.p.m. including cutting oils, lubricating oils and other industrial liquids. Long and continuous filtration cycle. Completely automatic self-cleaning. Wide range of porosities.

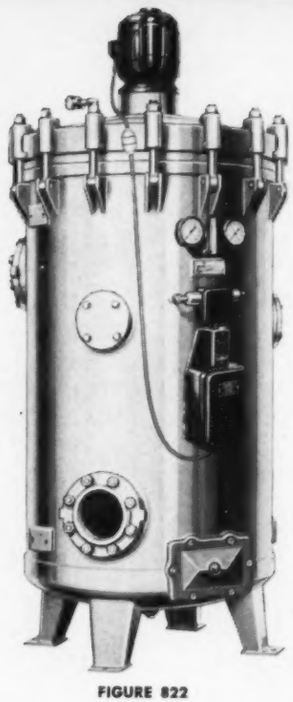


FIGURE 822

Filtering units and automatic self-cleaning system of Figure 822

The Bowser staff of engineers is available for counsel and recommendations on the specific filtering requirements of your plant. Write today.

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LIQUID CONTROL SPECIALISTS SINCE 1885

GENERAL PURPOSE FILTER

STORING AND DISPENSING

PIPE SEALING COMPOUND

EXPENDABLE CARTRIDGE FILTER

COOLANT FILTER

manager of Roots-Connersville Blower Corporation, Connersville, Indiana, one of the dresser industries.

Mr. Tatman has been with Roots-Connersville since his graduation from Purdue University in 1902. He is a vice president of the Compressed Air & Gas Institute.

Mr. Avery, well known for his activities in centrifugal compressor engineering for the past 22 years, was graduated from the United States Naval Academy in 1923. He then joined the engineering staff of General Electric Company and in 1926 became a project engineer for American Brown Boveri Company. Before becoming president of Roots-Connersville, Mr. Avery was manager of the blower and compressor department of Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin.

Obituaries

Lee A Daines, 52, vice president and general sales manager of Heppenstall Company, Pittsburgh, Pennsylvania and Bridgeport, Connecticut, died very suddenly early on the morning of March 29, in Miami, Florida.

He was born in Jackson, Michigan, on January 28, 1894. Mr. Daines attended Albion College and the University of Michigan. During World War I, he served in the Air Force.

Between 1920 and 1923, Mr. Daines lived in Pittsburgh, Pennsylvania, being then associated with the United States Chain and Forging Company and the Witherow Steel Company. In 1923, Mr. Daines joined Heppenstall Company and was assigned to the Detroit office. A few years later he was transferred to the Company's Chicago office, where he was district manager until almost a year ago. On May 1, 1945, Mr. Daines was elected to the position he held at the time of his death. He had been a director of the company for eight years.

E. B. Elliott, an engineer with the Solvay Process Company of Syracuse, New York died recently. Mr. Elliott had been a member of the Association of Iron and Steel Engineers for almost thirty years, having been elected a member in April, 1918.

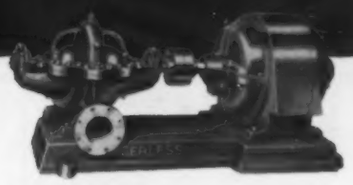
Fred J. McCullough, sales manager of the Maloney Electric Company, Chicago, Illinois, passed away on January 26th, 1946. Mr. Maloney had been a member of the A. I. S. E. since 1940.

Edward J. Finkbeiner, a vice president of American Car and Foundry Company, died suddenly on March 23 at his home in East Orange, New Jersey, at the age of 60. Mr. Finkbeiner had been associated with the company for 42 years.

He was born in Sebewing, Michigan and was educated in the public schools of Howell, Michigan. He entered the employ of ACF in July, 1904 as a clerk in the auditing department at the Detroit, Michigan, plant, advancing steadily to positions of importance. In May, 1922 he transferred to the operating department in New York as general supervisor in the production department of ACF, and eventually he became closely associated with the president's office. During the two World Wars he rendered invaluable service to the company and to the nation.

MODERN CENTRIFUGAL PUMPS

Peerless Offers a Complete Line of Vertical and Horizontal Types.



PEERLESS Type A Pump For General Service; Single Stage, Double Suction.

In the past few years new applications of principles of hydro-dynamics have served to render obsolete many types of older designs of Centrifugal pumps.

With the recent acquisition of the Dayton-Dowd Company of Quincy, Illinois, Peerless Pumps manufactures a complete line of modern horizontal and vertical centrifugal and turbine pumps, adapted for use in an almost endless variety of applications. Engineering assistance and literature available.

PEERLESS PUMP DIVISION
Food Machinery Corporation
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DESIGNERS WANTED:

First Class Designers on medium and heavy machinery. Must be experienced on rolling mill machinery and allied products. In reply state age, experience in full, education and salary expected.

TREADWELL ENGINEERING COMPANY
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WANTED

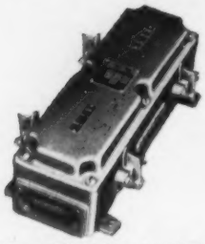
Superintendent of Mechanical and Electrical Maintenance. Blast Furnace, Coke and Chemical Plants. Pittsburgh district. State full qualifications. Replies confidential. Box 473, Iron and Steel Engineer, 1010 Empire Building, Pittsburgh 22, Pennsylvania.

CROUSE-HINDS

Panelboards and Distribution Centers

The illustrations show a representative selection from the dozens of different CROUSE-HINDS Panelboards—each designed for its own purpose.

No. 6
of a series of advertisements which demonstrate that CROUSE-HINDS "complete line" means much more than just a range of sizes — there is a wide variety of highly specialized types in each classification.

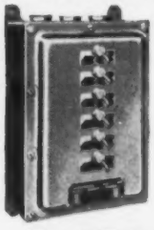


Type YSW Vaportight and Weatherproof Condulet with Four Circuit Breakers

Type DVS Dust-Tight Vaportight and Weatherproof Condulet with Two Circuit Breakers

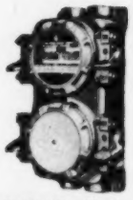
Type GUSC Explosion-Proof, Dust-Tight and Weatherproof Condulet with Two Circuit Breakers

Type ESP Explosion-Proof, Dust-Tight, Vaportight and Weatherproof Panelboard with Four Circuit Breakers

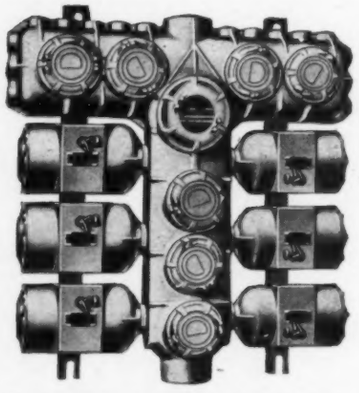


Type DVS Dust-Tight Vaportight and Weatherproof Condulet with Six Circuit Breakers

Type DVP Dust-Tight and Vaportight Panelboard with Sixteen Circuit Breakers



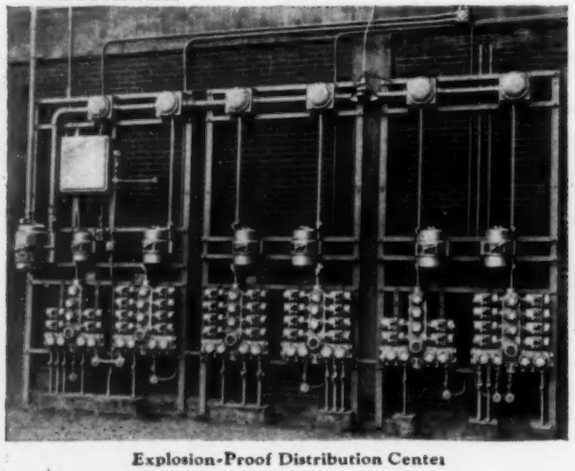
Type GUSC Explosion-Proof, Dust-Tight and Weatherproof Condulet with Four Circuit Breakers



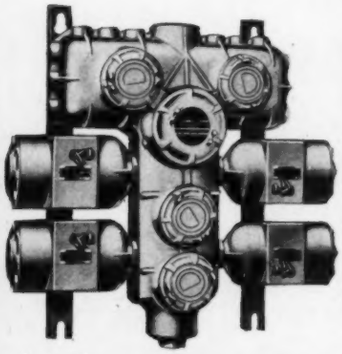
Type EDP Explosion-Proof, Dust-Tight, Vaportight and Weatherproof Panelboard with Six Circuit Breakers

Type WBP Weatherproof Panelboard with Six Circuit Breakers Can Be Padlocked

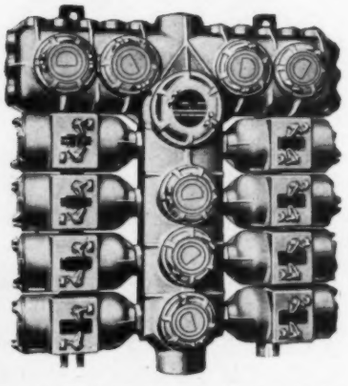
Type DVP Dust-Tight and Vaportight Panelboard with Eight Circuit Breakers



Explosion-Proof Distribution Center



Type EDP Explosion-Proof, Dust-Tight, Vaportight and Weatherproof Panelboard with Four Circuit Breakers



Type EDP Explosion-Proof, Dust-Tight, Vaportight and Weatherproof Panelboard with Sixteen Circuit Breakers

A Nationwide Distribution Through Electrical Wholesalers

Complete listings of each type are in Condulet Catalog No. 2500.

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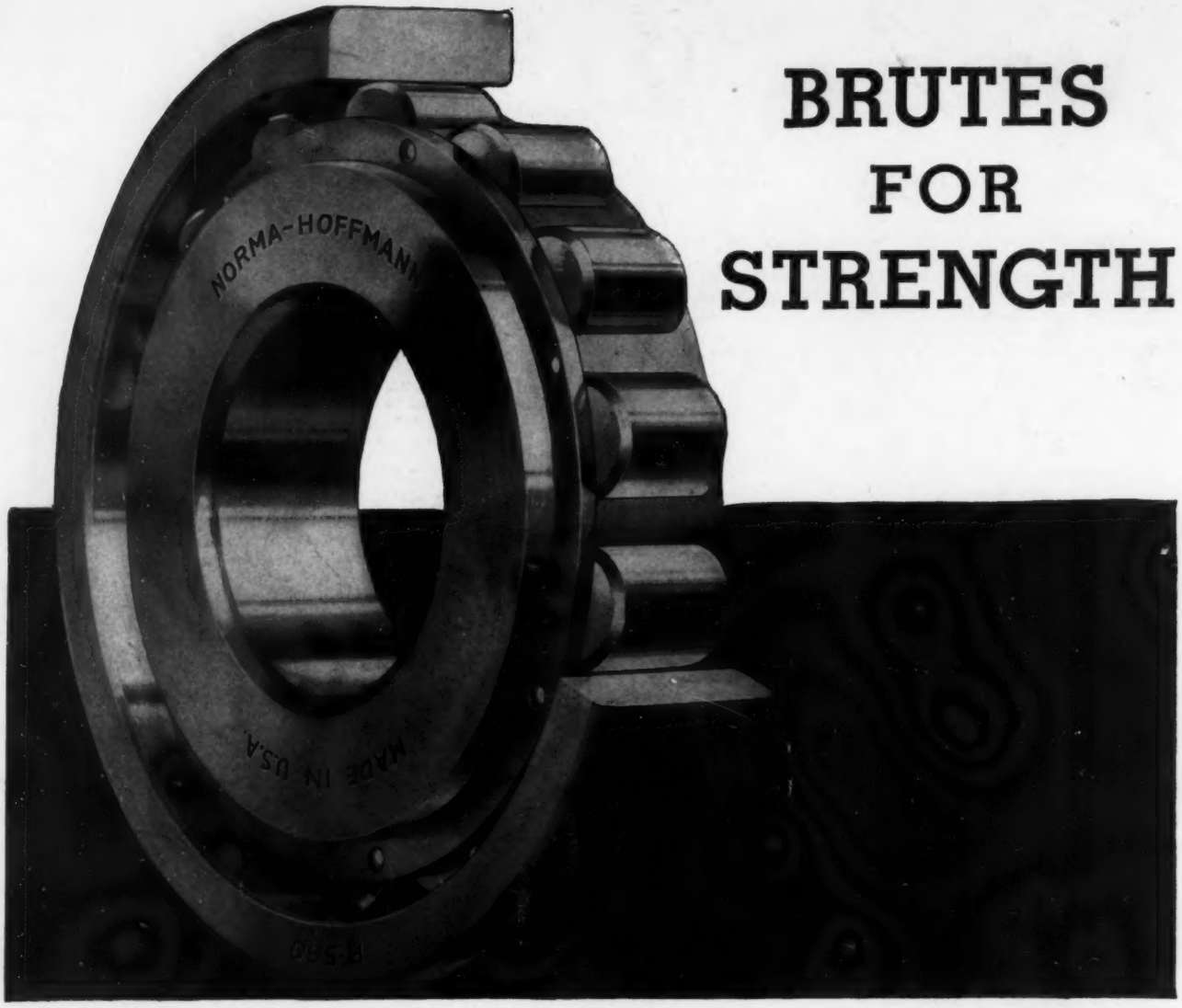

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THE outstanding performance records made by NORMA-HOFFMANN PRECISION ROLLER BEARINGS under the heaviest and most exacting duties, are the logical result of the following distinctive factors:

Full line contact of rolling surfaces, affording a larger radial load capacity for continuous and intermittent service than any other type of single-row bearing, and providing a temporary overload capacity 50% above normal catalog rating, with greater resistance to shock and vibration.

Highly durable, completely machined and balanced bronze retainer.

Lower frictional coefficient under heavy loads than any other single-row anti-friction bearing—due to extreme precision and design characteristics.

Test these PRECISION ROLLER BEARINGS in your own hardest service; remember that they have all the high speed qualities of the best ball bearings, and are interchangeable, size for size, with all single-row metric ball bearings.

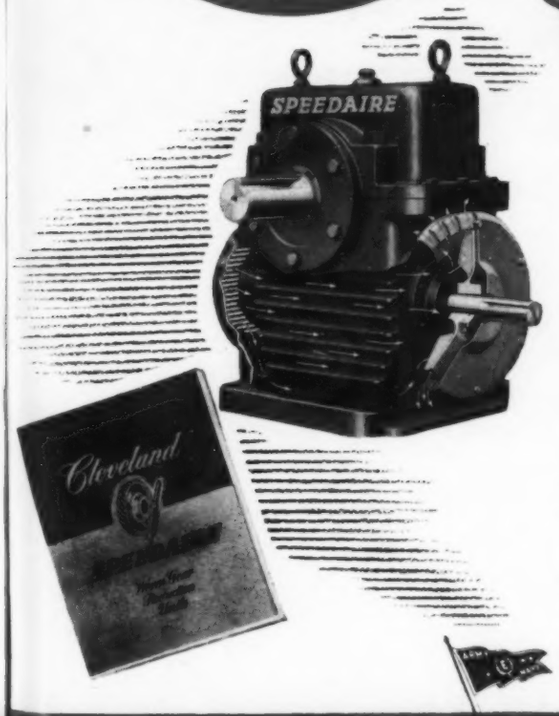
Write for the catalog. Let our engineers work with you.

"NORMA-HOFFMANN"

PRECISION BALL, ROLLER and THRUST BEARINGS

NORMA-HOFFMANN BEARINGS CORPN., STAMFORD, CONN. U.S.A.

Full Rated Capacity —but *Half the Size!*



With the new Cleveland Speedaire Worm Gear Unit it is possible to obtain an operating capacity equal to that of a standard worm gear unit having approximately double the frame size.

Speedaire—the *new* Fan-Cooled Unit—continually removes heat by means of a high-velocity air stream scouring the outer surfaces of the oil reservoir. Because Speedaire stays cool, it will give you More Horsepower per Dollar.

You can install this modern, right-angle Drive Unit on many applications where you have used other types heretofore. Profit by Cleveland's latest development. Send for the Speedaire Catalog today.

The Cleveland Worm & Gear Company, 3278 East 80th Street, Cleveland 4, Ohio.

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In Canada: PEACOCK BROTHERS LIMITED

Cleveland **SPEEDAIRE** *Worm Gear Reduction Units*

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HODGE-PODGE CONTROL IS EXPENSIVE!

This is a typical installation of attractive, unit-type Cabinetrol.

Trim, Modern CABINETROL Cuts Installation Time and Cost

Rambling, space-taking racks are a thing of the past. Control in the *modern* steel mill is compact, centralized G-E Cabinetrol. It's attractive in design, safe to operate, and it costs no more!

Cabinetrol saves installation time and expense because it's a single, self-supporting unit. No cumbersome frames—no cluttered walls. Just one attractive, all-metal unit that will greatly enhance the appearance of your mill.

The savings in installation cost that you get with Cabinetrol usually far outweigh its higher original cost. Only two operations are necessary—placing the unit in the designated location and connecting external power, motor, and control leads.

IT'S PRE-ENGINEERED

Cabinetrol is based on the use of standard enclosures equipped with the right combination of standard control devices. Each unit is pre-engineered to meet your specific requirements. All starters and accessory equipment necessary to your application are incorporated in the Cabinetrol unit before it is shipped.

PROTECTS YOUR OPERATORS

Because metal-enclosed Cabinetrol is complete deadfront, it offers your operators and serviceme maximum protection. Each motor control is installe in an individual sheet-steel compartment with an inte locking door. Operating mechanisms for moto circuit switches and air circuit-breakers are availabl from the front of the panel.

LET US HELP YOU equip your plant with co-ordinate control. We'll be glad to work with you now—to pr vide a Cabinetrol system specially engineered for yo plant—and, if you desire, to help you fit Cabinetrol int your over-all plans.

If you'd like more facts about Cabinetrol ask fo Bulletin GEA-3856. *Apparatus Dept., General Electr Company, Schenectady 5, N. Y.*

G-E INDUSTRIAL CONTROL

GENERAL ELECTRIC